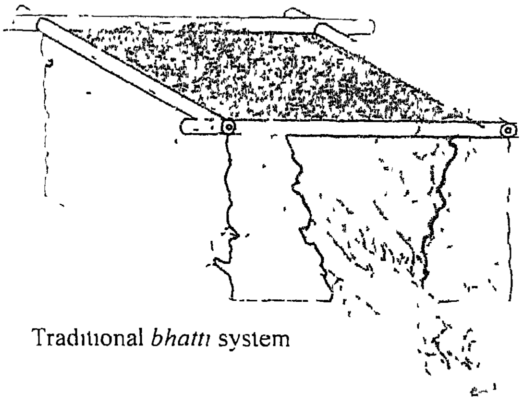
December 1998

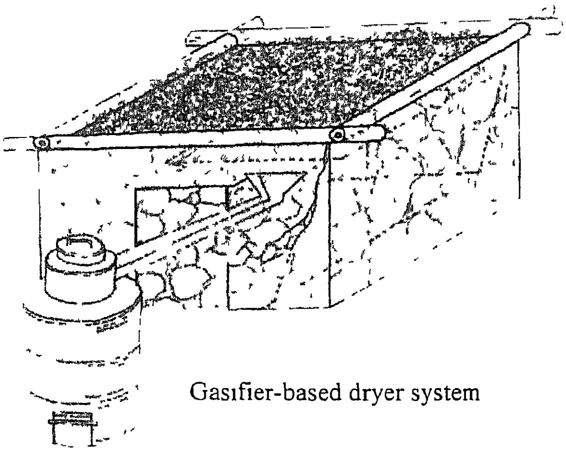
Design, development and field testing of an advanced cardamom curing chamber prototype for Sikkim (Action Research Phase)

Project report submitted to

Indo Swiss Project Sikkim (ISPS)
Gesar Khang, National Highway 31A
Gangtok - 737 102 (Sikkim)



Traditional *bhatti* system



Gasifier-based dryer system

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Acknowledgments

Work described in this project report was performed under the project "Design, development and field testing of an advanced cardamom curing chamber prototype for Sikkim (Action Research Phase)" sponsored by Indo Swiss Project Sikkim (ISPS), Gangtok. The authors are grateful to ISPS for sponsoring this project. Mr K P P Kurup and Dr P J Joseph (Liaison Officer, ISPS) and Dr A Tarnutzer (Senior Visiting Advisor, ISPS) who took lot of interest and gave constant encouragement in carrying out this study and authors are indeed grateful to them. The authors are grateful to Dr Urs Heierli (Counsellor and Head, SDC, New Delhi) and Dr Veena Joshi (Head, Energy and Environment, SDC, New Delhi) for their keen interest shown in the project and continued guidance received from time to time throughout the execution of the project report. Special thanks are due to Mr S Lama (former Secretary, Department of Horticulture, Sikkim) and Mr G K Gurung (Principle Director, Department of Horticulture, Sikkim) for their whole hearted encouragement and co-operation during the field testing activity Thanks are also due to Mr U Bhutia and Mr Jeevan Kumar Chhetri of Department of Horticulture, Sikkim and all farmers and officers of Spices Board as well as State Horticulture Department for their help and active co-operation in carrying out field testing of gasifier-based system in Sikkim The support and encouragement of Dr R K Pachauri, Director, Tata Energy Research Institute (TERI) is gratefully acknowledged Thanks are due to Ms Rajani Kumari and Mr Kamal Sharma for secretarial assistance and all colleagues of TERI who have helped in several matters during the course of this study

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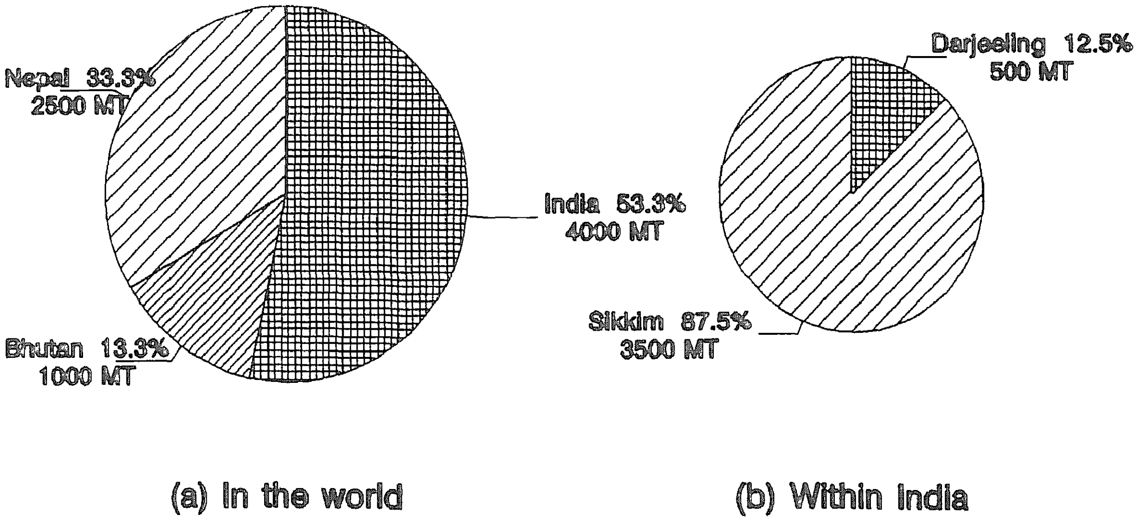
CHAPTER 1

Introduction

Large-cardamom (*Amomum Subulatum Roxburgh*) is the native cash crop of Sikkim. With annual production of 4000 MT, India is the largest producer of cardamom with 54% share in the world production, followed by Nepal (33%) and Bhutan (13%) Within India, Sikkim contributes to over 85% of total production and balance comes from Darjeeling district of West Bangal (See Figure 1 1) It is the main cash crop of Sikkim producing about 3850 MT annually from approximately 17,000 holdings with total cultivated area of about 23,500 ha[1,2] A primitive smoking method of curing/drying (locally called as traditional *bhatti* system) of cardamom is used which produces poor quality dry cardamom and is very inefficient It is estimated that about 20,000 MT of fuel wood is consumed annually for drying large-cardamom in Sikkim alone As cardamom curing is small farmers business (large number of units having small cultivated areas), farmers are not in a position to try improvements in the design on their own



(a) In the world

(b) Within India

Figure 1.1. Region wise production of cardamom (a) in the world (b) within India

1.1 Processing of large-cardamom in traditional *bhatti*

The fresh large-cardamom capsules contain about 70-80% moisture (on wet basis) depending upon the maturity level of the capsule at the time of plucking Unlike in southern India, where

only matured capsules are plucked, the whole cardamom capsule bunch is plucked in Sikkim Later on each capsule is separated from the bunch/flower and cleaned for drying In order to achieve longer storage life and also to bring out its aroma, it has to be dried to reduce the moisture content to a level below 10% (on wet basis) In the traditionally followed system of drying, the fresh cardamom capsules are dried in locally made *bhattis* shown in Figure 1 2. It consists of 2 ft thick stone wall structure on all four sides with opening of about 3' × 4' in the front to make the fire

Fresh cardamom capsules are spread in a 10-12 inch thick bed on the mesh structure placed on the stone walls Nearby trees are cut into logs and these wet logs are then burnt inside the *bhatti* structure below the cardamom bed Thus the cardamom bed is exposed to the thick smoke generated during burning of wet wood It takes about 30-50 hours to dry the cardamom

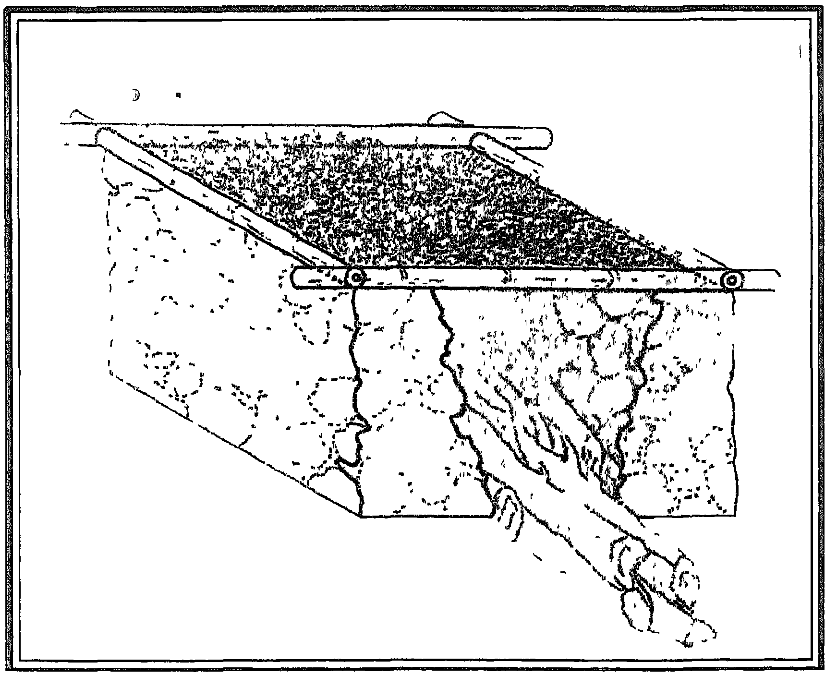


Figure 1.2. Traditional *bhatti* system for drying large-cardamom

Traditional *bhattis* have a very low thermal efficiency level of the order of about 5-15%, a specific fuel consumption of 0 8 to 2 3 kg per kg of fresh cardamom[3]. Exposure to excessive smoke gives smoky-blackish appearance to dried capsules. Lack of control on fire often leads to localized over-heating causing charring and reduction of volatile oil content.

1.2 Performance of traditional *bhatti*

Under an earlier project an attempt was made to carry out a detailed study of the existing cardamom curing chambers to identify bottlenecks in the present system resulting in lower efficiency and non-uniform drying and to suggest possible solutions for improvement in its energy efficiency through technological upgradation[3]. In order to carry out this task an extensive survey of cardamom curing chambers in Sikkim was undertaken to collect on the spot information and more process details. At three selected units, two in north district and one in south district of Sikkim, detailed information was collected through measurements in the field for one complete cardamom curing batch operation (See Table 1.1)

Table 1.1. Summary of experimental data for the cardamom curing units studied

Unit Name	Mangan	Naga	Ravangala
Fresh cardamom capsules (kg)	747 0	507 5	580 0
Cured cardamom capsules (kg)	221 0	134 0	143 0
Fuelwood consumed (kg)	860	1149	464
Total drying time (h)	35	40	26
Thermal efficiency (%)	10 8	5 4	15 5
Specific fuel consumption (kg fuel per kg fresh cardamom)	1 15	2 26	0 80

From the experimental data analysis, it was concluded that the present system operates with very low thermal efficiencies, of the order of 5–15%, associated with many disadvantages resulting in poor performance and quality such as

- high fuel consumption
- non-uniform drying
- poor quality — looses original natural colour due to charring and becomes smoky
- constant attention of operation is required for managing fire; maintaining low flame preventing fire hazards, and turning over the bed of cardamom

1.3 Alternate system design

The alternative design should improve the performance on two fronts

- quality of dried cardamom capsules
- fuel efficiency

Considering these requirements, the use of simple updraft wood gasifier seems to be the most promising option for the following reasons

- better conversion (solid to gas) efficiency (above 70%)
- better control on burning (handling gaseous fuel)
- production of clean flue gases (as gas is burnt)

This system has several advantages as follows·

- Better quality of dried product as initial smoke can be diverted and only gaseous fuel is burned
- It can be used as an add-on system to existing *bhattis*
- Low incremental cost (used oil barrel, fire clay lining)
- Simple design, can be fabricated in workshops of rural areas
- Better thermal efficiencies due to controlled burning rates, small insulated combustion chamber, controlled excess air levels

As a follow-up activity of the study, ISPS (Indo-Swiss Project Sikkim) has given an assignment to TERI (Tata Energy Research Institute) to design, develop and field test such an advanced gasifier-based large-cardamom drying system for its application in Sikkim The project is divided into two phases

Phase-1. Action research phase: (Duration: 2 years)

In this phase, the prototype unit of advanced cardamom curing system will be designed and developed through testing at TERI as well as field testing of prototype unit in Sikkim The design will be modified to arrive at a marketable product, based on experience gathered and feedback received during the field testing, market trials and preliminary techno-economic and user acceptability study At the end of the action research phase, based on an assessment of the reaction of the producers and traders to the new system and quality of the product produced though its use, a decision to go ahead for the next pilot scale phase will be taken only if this feedback is positive

Phase-2. Pilot scale phase: (Duration: 1 year)

In this phase, which will be a follow-up of the successful completion of phase-1 in developing advanced marketable cardamom curing system, the commercial pilot scale plant of the advanced cardamom curing system will be operated to test its marketability, viz. user acceptability and financial benefits Based on the feedback received the strategy for the large scale promotion of the advanced system in Sikkim will be formulated

1.4 Objectives

The broad objective of the project is to develop and promote an advanced cardamom curing chamber in Sikkim with special reference to improvement in quality of dried cardamom and fuel efficiency. This can be further sub-divided into following two heads:

(i) *Technical*: Development of an advanced technology/system for cardamom curing process producing improved quality of the cardamom with better fuel efficiency.

(ii) *Socio-economic*: To carry out the social acceptability study of the developed system in Sikkim and its economic viability This will also include market assessment study for the improved quality cardamom which is obtained through technology upgradation

1.5 Work elements

The following is the list of activities identified in the original project proposal in order to achieve the project objectives of Action Research Phase of the project.

1. Collection of additional information about critical parameters in cardamom curing process.
2. Obtaining basic data regarding parameters influencing drying rates and drying characteristic of large-cardamom.
3. Design, fabrication and testing of prototype unit at TERI
4. Evolving an advanced system design for trial field testing
5. Selection of sites for field testing, making operation-cum-marketing arrangements for trial field testing.
6. Installing the advanced systems at selected 2–3 sites in Sikkim.
7. Field testing of advanced systems for its technical performance monitoring as well as test marketing of the product to assess reactions of producers and traders.
8. Analysis of the performance evaluation data collected during field testing
9. Evaluation of cardamom quality from advanced system in lab and trading centers
10. Design modifications based on the feedback received through trial runs
11. Further trial runs on modified system at TERI
12. Installing the modified (Mark-II) system design (1–2 each in different altitude regions) in the field units
13. Performance evaluation of the modified systems in the field
14. Economic analysis and user acceptability and marketability study of advanced system.
15. Analysis of data collected on system performance evaluation
16. Finalization of advanced system design for large scale promotion

17. Assessment and evaluation of the action research phase (first two seasons) through project review workshop to decide whether to proceed for next pilot scale phase

This report gives detailed account of the project work carried out during the two year long Action Research Phase of the project in order to achieve the above objectives

CHAPTER 2

Drying characteristics of large-cardamom

In order to design any new dryer system, basic drying parameters of the item to be dried, such as critical moisture content, drying rate under different operating conditions etc are necessary. Such a basic information is not available for many spices including large-cardamom. This section gives detailed account of efforts made to obtain drying parameters of large-cardamom.

In order to obtain the basic general drying parameters of large-cardamom, an assignment was subcontracted to Prof. V G Rao of Chemical Engineering Department, IIT, Bombay. To carry out experiments for this purpose in laboratory, 12 batches (10 kg each) of fresh cardamom capsules were sent at regular intervals from Sikkim by courier/speed post In order to preserve the sample afresh, it was first sealed in a polythene bag which in turn was sealed with stitching in plastic coated rexin bags which were sent by parcel in cartons wrapped in parcel cloth.

Table 2.1 shows the details about the batches of cardamom material dispatched from Sikkim to IIT, Bombay. The table also includes the cardamom batches with which trial experiments were conducted. Three trial experiments were conducted to minimize possible errors, to standardize the experimental procedure and to decide the frequency of sampling.

Table 2.1. Details about laboratory experiments carried out at IIT Bombay

Batch no	Dispatched from Sikkim on	Received at IIT Bombay on	Experiment conducted on	Experiment no	Air flow rate (lit/min)	Air temperature (°C)
1	13 09 96	17 09 96	18 09 96	Trial Expt	—	—
2	12 10 96	14 10 96	15 10 96	Trial Expt	—	—
3	12 10 96	14 10 96	17 10 96	Trial Expt	—	—
4	15 10 96	22 10 96	23 10 96	1	580	70
5	17 10 96	22 10 96	25 10 96	2	690	82
6	19 10 96	22 10 96	26 10 96	3	580	82
7	23 10 96	29 10 96	30 10 96	4	690	70
8	28 10 96	04 11 96	04 11 96	5	580	90
9	29 10 96	04 11 96	05 11 96	6	690	90
10	28 10 96	04 11 96	07 11 96	7	460	90
11	02 11 96	07 11 96	08 11 96	8	460	82
12	02 11 96	07 11 96	10 11 96	9	460	70

A total of nine drying experiments were conducted at different temperatures and air flow rates as shown in Table 2.1. As can be seen from the table, drying data was obtained at hot air temperatures of 70, 82 and 90 °C and at each temperature for three air flow rates of 460, 580 and 690 lit/min.

2.1 Experimental setup

The experimental set-up used for generating drying data for large-cardamom, shown schematically in Figure 2 1, essentially consists of

(i) a dryer,
(ii) an air blower,
(iii) an air heater, and
(iv) a flow meter

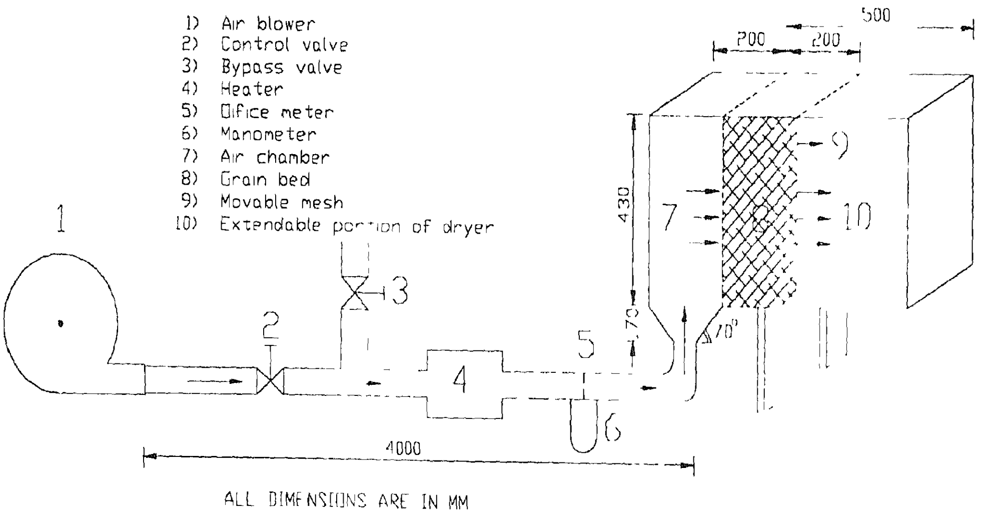


Figure 2.1. Schematic diagram of experimental set-up for drying large-cardamom

Figure 2 2 gives a photograph showing the overall view of experimental set up established in the laboratory of IIT Bombay, while Figure 2 3 shows close-up of the dryer portion of the setup

Figure 2.2. Overall view of experimental set-up established at IIT Bombay

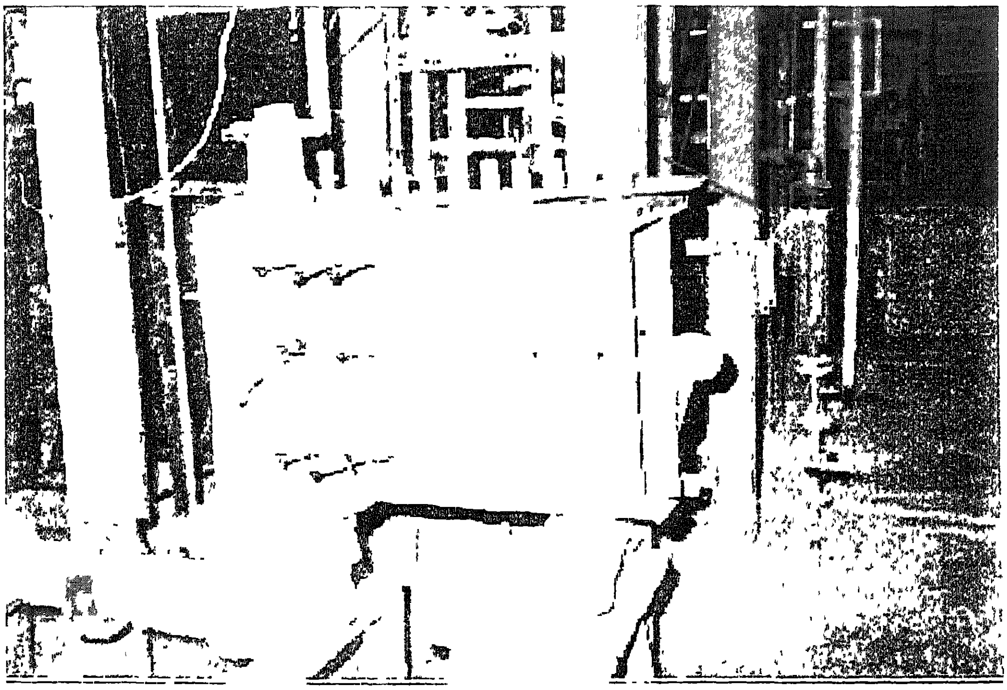


Figure 2.3. Close-up of dryer with provision to vary cardamom bed thickness

(i) Dryer

The dryer is made of mild steel. It consists mainly of two sections, an air chamber and a drying chamber. These two sections are rectangular in cross-section and separated by a metal wire mesh of thickness 0.002 m. The air chamber has the dimensions of 0.430 m height, 0.2 m breadth and 0.2 m thickness The drying chamber also has the same dimensions for height and breadth and a provision for varying the thickness of cardamom bed upto a maximum of 0.5 m

The dryer is provided with facilities to measure temperatures and humidity of inlet (heated air) and outlet air from the dryer. The drying chamber is also provided with provisions to measure the temperatures of cardamom bed at 5 cm, 15 cm and 25 cm from top along the height of the bed. The temperatures were measured by mercury thermometers and relative humidities were calculated from the measurements of wet bulb and dry bulb temperatures.

(ii) Air blower

It is a centrifugal blower with a rated capacity 0.5 m^3/s coupled directly to 7.5 hp induction motor.

(iii) Air heater

It consists of 6 heating coils of 1 5 kW capacity each. Input voltage can be controlled with the help of dimmerstat to get the desired temperature of hot air.

(iv) Flow meter

An orifice of diameter 0 02 m was fixed in a G I. pipe of 0 078 m inside diameter to make the orifice meter. Pressure drop across the orifice was measured with a U-tube manometer using water as a manometric fluid. The orifice meter was calibrated against a standard rotameter

2.2 Experimental procedure

At the start of experiment, the blower was switched on and the desired flow rate was adjusted with the help of orifice meter and desired temperature was attained by regulating heater voltage About one hour is required to attain steady state conditions.

Meanwhile fresh cardamom mass was removed off the pack and immediately spread over a plastic sheet on the flat table and thoroughly mixed Around 8 kg of good quality thoroughly mixed fresh cardamom was taken for the experiment. After attaining the desired steady state conditions (hot air temperature and flow rate), the cardamom feed was poured in the drying chamber and thickness of chamber was so adjusted by the movable mesh such that all the space in drying chamber was fully occupied and yet the cardamom mass was not pressed hard The initial thickness was about 20 cm

The cardamom sample was taken from the dryer at regular intervals for determining moisture content level. The thickness of drying bed was so adjusted that cardamom mass would occupy all the drying chamber space available The drying was continued till the moisture content in the cardamom was reduced below 10% on wet basis.

2.3 Results of drying experiments

The drying data for large-cardamom at three temperatures and three air flow rates is given in graphical form in Figure 2.4. It gives the variation of moisture content (dry basis) as a function of drying time.

From the Figure 2 4 it can be seen that the slope of moisture content versus time curve is constant upto a certain drying time and then decreases indicating two regions of drying, namely, constant rate and falling rate period The moisture content versus time of drying data for constant rate period as well as falling rate period were fitted by least square regression technique to polynomial equations to give the variation of moisture content as a function of time. These polynomial equations were used to calculate drying rates Figure 2 5 gives variation of drying rate (kg/h per unit cross sectional area of dryer perpendicular to air flow) with moisture content for large-cardamom under different operating conditions, clearly showing constant and falling rate periods as well as critical moisture contents The critical moisture contents were found to be in the range of 30 to 46% (on wet basis) depending upon the operating conditions Critical moisture content is the moisture content at which constant rate drying (removal of surface unbound moisture) period ends and falling rate drying (removal of inner bound moisture) period starts

Table 2.2 gives data regarding variation of drying time for drying cardamom from an initial moisture content of 80%. The drying time required to reduce moisture content from initial value decreases as air flow increases at a constant air temperature Similarly the drying time decreases as air temperature increase at a constant air flow rate From an experimental data of drying time an empirical correlation for drying time in terms of operating variables was obtained by least square regression analysis

$$t = \frac{222}{V^{0.83}\,T}$$

where,

V = velocity of air, m/sec

T = temperature of air, °C

t = drying time, h

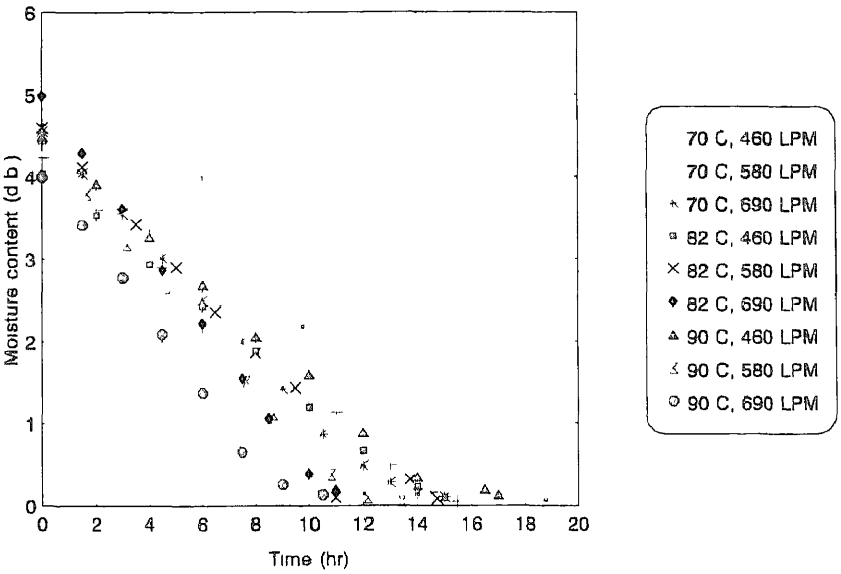


Figure 2.4. Variation of moisture content (d b) with time

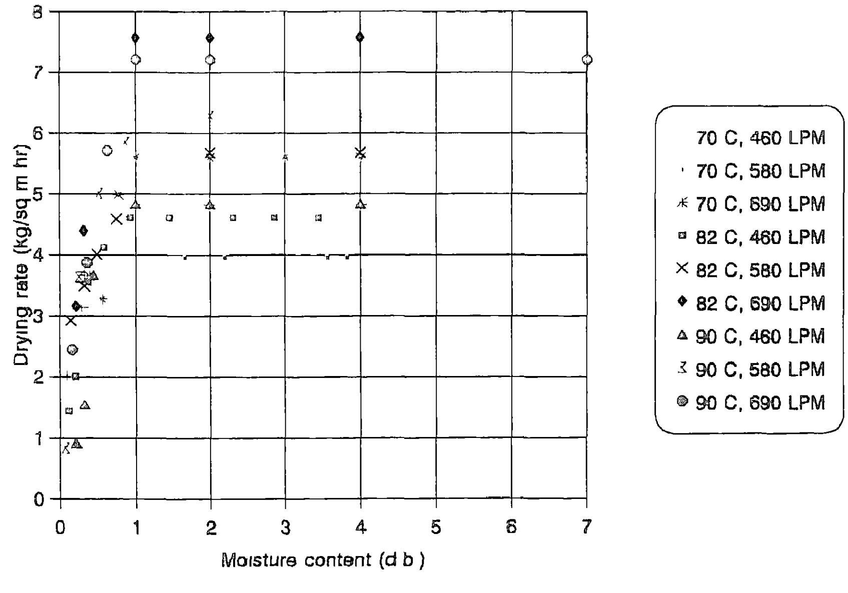


Figure 2.5. Variation of drying rate with moisture content (d.b.)

The drying times calculated from the correlation are compared with the experimental values in Table 2.2 and it can be seen that the agreement is good.

Table 2.2. Drying time data for large-cardamom

Drying conditions		Drying time (h)	
Air temperature (°C)	Air flow rate (LPM)	Experimental	Calculated
82	690	9 35	–
82	580	12 75	12 45
82	460	14 75	15 11
70	690	12 85	12 65
70	580	14 35	14 59
70	460	16 60	17 35
90	690	9 35	9 83
90	580	11 50	11 35
90	460	14 25	13 49

Note Drying time is for reducing moisture content (on wet basis) from 80% to 9%

Empirical co-relation is valid for initial bed thickness of 20 cm and for range of operating conditions experimented

From the data it can be seen that ideally it is possible to dry large-cardamom in less than 15 hours if one maintains low flow rate and higher temperatures This can be achieved by reducing dilution of flue gas with ambient air which lowers the temperature. The reason for trying such low flow rates here was to bring it closure to natural draft flow rate conditions which will be existing in the actual field conditions

CHAPTER 3

Prototype development

During the survey in Sikkim to study the existing traditional *bhatti* system, the following general observations were made which are important while considering/designing any alternative system for cardamom drying in Sikkim

- The *bhattis* are made up of locally available construction material with only few days of labour cost Also *bhattis* are used for only 1-2 weeks in the year Thus there will be an inherent resistance from the farmers for huge initial investment in trying any new option
- These *bhattis* are located in the cardamom plantations which are located in remote hilly areas which are difficult to access by road. Therefore the new system should not involve very heavy structural/mechanical components or machinery
- In most of the *bhattis* electricity connection is not available, therefore use of electrically operated system components (e g blower, pump) will have to be avoided in alternative system design
- Since fuel wood is available in the field, cardamom being a shade loving plant, farmers will not be attracted towards mere fuel saving device, but it will have to offer other benefits like improving quality, working environment etc
- The average quantity of fresh cardamom dried in one batch ranges between 10-15 *maunds* i e 400-600 kg

Considering the extent of use of the *bhatti* in a year, and the conditions prevailing in hilly sites, the following points are important while attempting any alternate design

- utilize locally available material to the extent possible
- minimize the incremental cost of the system

Considering these limitations and requirements, the use of wood gasifier seems to be the most promising option A brief description of gasification technology is provided in the following section

3.1 Biomass gasification

Biomass gasification is a thermo-chemical reaction which converts solid fuel into gaseous fuel. Gasification incorporates partial combustion followed by reduction due to char, in which an insufficient quantity of air (about 30% of stoichiometric air required for complete combustion) is supplied to obtain a mixture of CO (carbon monoxide), H_2 (hydrogen), CH_4 (methane, CO_2 (carbon dioxide), and N_2 (nitrogen) called as producer gas This combustible gas then can be burnt to get clean products of combustion

There are three types of biomass gasifiers depending upon fuel and air movements within the gasifier (See Figure 3.1)

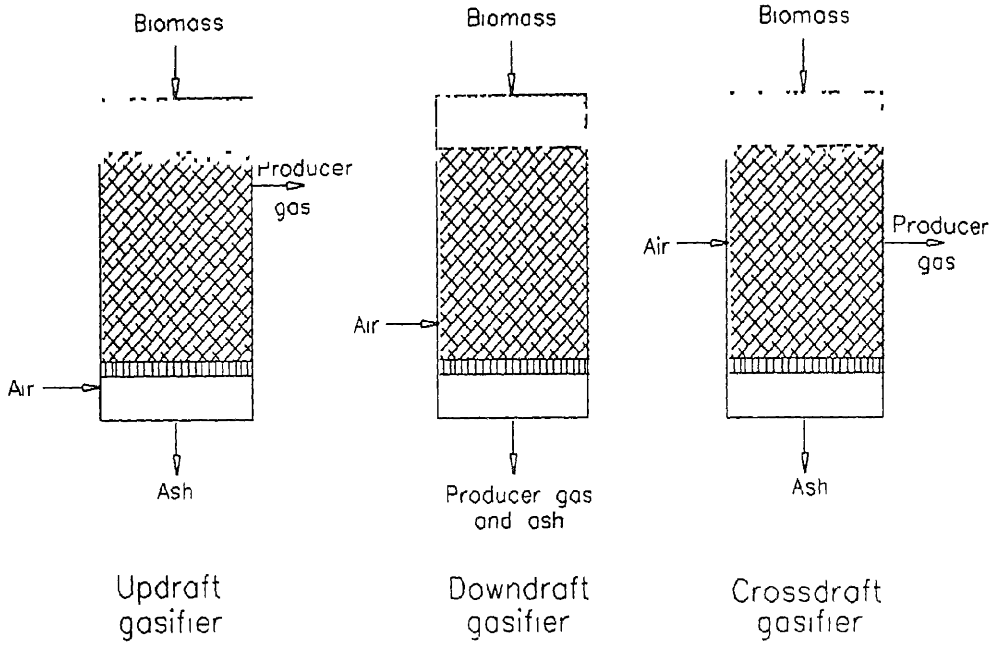


Figure 3.1. Different types of biomass gasifiers

(a) Updraft gasifier

Here the air enters the gasifier from the bottom and producer gas is taken out from top The gas has a relatively higher quantity of tar and soot particles, but it gives better conversion efficiency It is therefore suitable when gas quality is not critical, e g for thermal applications where the tar in the gas also gets burnt in the burner.

(b) Downdraft gasifier

In this gasifier air enters from middle and producer gas is drawn from the bottom The gas quality (tar and particulate content) is superior in this and therefore it is commonly used for engine applications for power generation

(c) Cross-draft gasifier

In this air enters from one side and producer gas is taken from other side The gas quality is in between that of updraft and downdraft gasifiers

Due to considerations of cost and ease of fabrication, the updraft gasifier design seems to be more suitable for incorporation in cardamom curing chambers.

3.2 Proof of concept: using *tandoor* as a gasifier for cardamom drying

In northern India, an oven called *tandoor* is used for making *rotis*. The *tandoor* oven is a simple furnace made by placing a fired earthern pot inside an empty oil barrel. The annular space between the earthern pot and the drum (barrel) is filled with a mixture of ash, stone chips, glass chips, etc. which not only acts as insulating material but also prevents the earthern pot from cracking due to thermal expansion and contraction on heating and cooling respectively

At TERI's Gual Pahari campus (which is about 32 km from Delhi on Gurgaon-Faridabad road) in Haryana state, preliminary trials on the possibility of using *tandoor* as an updraft gasifier were undertaken On the top of *tandoor* an arrangement was made to burn the producer gas At the bottom a small rectangular air inlet with a damper was provided to supply a controlled (insufficient) quantity of air required to achieve gasification Figure 3.2 shows the flame of the producer gas obtained through use of *tandoor* as a updraft gasifier. The schematic diagram of the set up is given in Figure 3.3. Here an arrangement was made to divert the smoke during initial firing period through a duct, which was also used for charging the fuel wood pieces. The photograph in the Figure 3.4 shows the gasifier in operation alongwith a cabinet tray dryer at Gual Pahari

Through several trial runs in which vertical temperature profiles were measured, it was decided to keep a gap of about half a meter between the burner and wiremesh which will hold cardamom bed, in order to obtain conditions close to the field operation.

3.3 Development of the first prototype unit for field testing

The present oval shape of the combustion volume (maximum diameter at the middle which reduces gradually on both sides) in the existing *tandoor* results in a lower fuel storage space, though it might be suitable for making *rotis* Also, it was thought that a better insulating material such as a high temperature refractory may help in maintaining higher fuel bed temperature in the combustion zone, resulting in an improved performance of *tandoor* as a gasifier. So a modified simple updraft gasifier was made at TERI's Gual Pahari campus by lining a used oil drum from inside with castable "supercrete" insulating material of 2" thickness (Figure 3 5). Several trial runs were made using this updraft gasifier at TERI to see that sufficient producer gas is obtained for drying large-cardamom. By controlling the position of the input air supply damper, the burning rate was maintained at around 10–15 kg/h giving about 25 to 40 Nm^3/h of producer gas

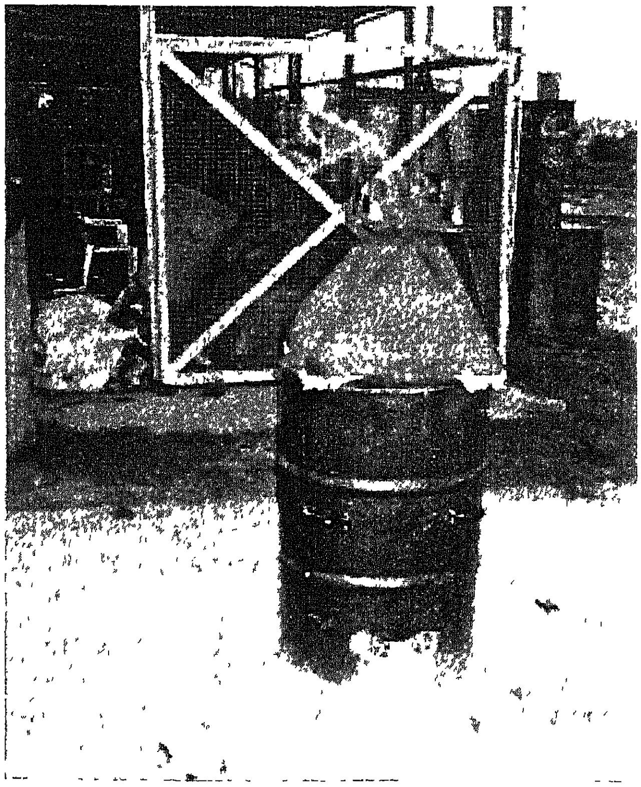


Figure 3.2. Flame of producer gas obtained through use of *tandoor* as an updraft gasifier

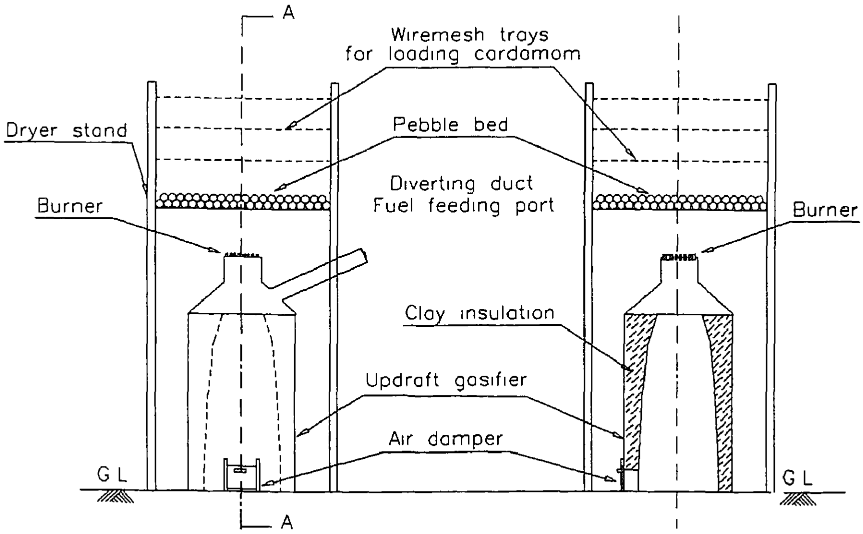


Figure 3.3. Schematic diagram of the set-up established at TERI's Gual Pahari campus

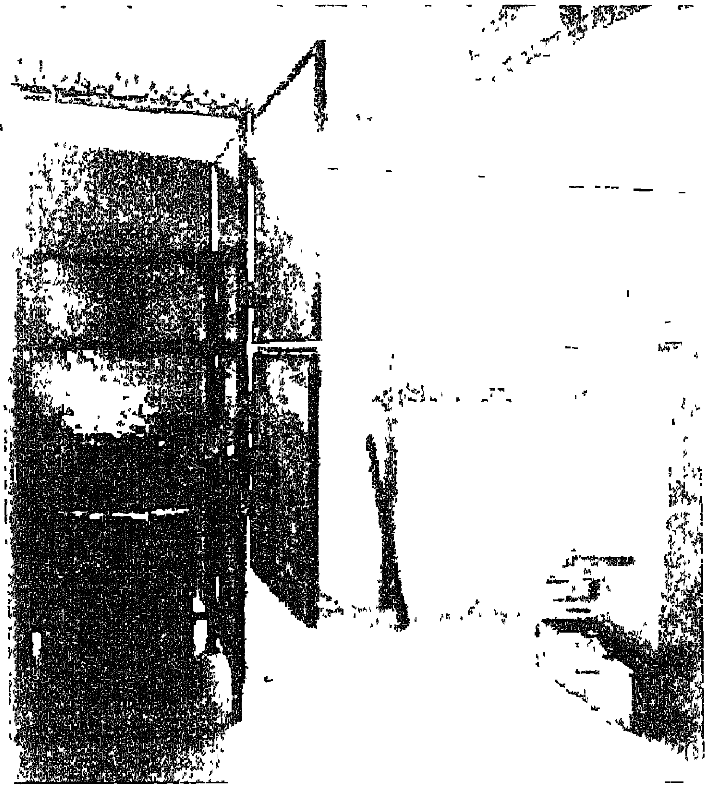


Figure 3.4. Gasifier in operation along with cabinet tray dryer

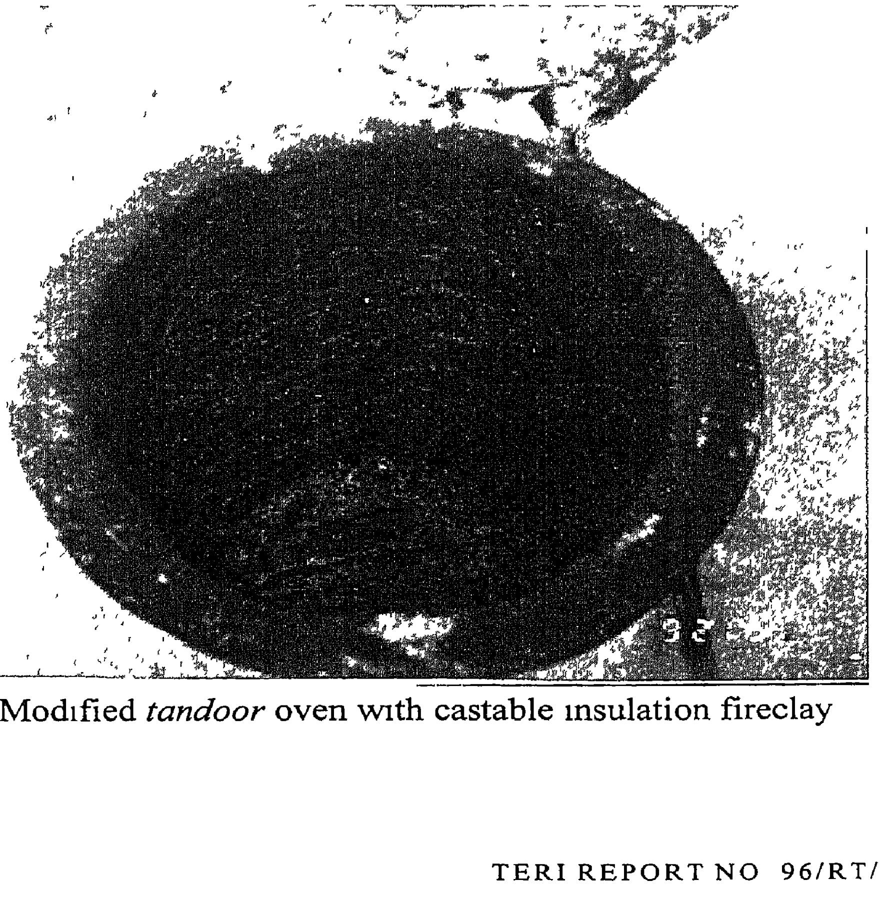


Figure 3.5. Modified *tandoor* oven with castable insulation fireclay lining

Burner design was also optimized by several trials starting from open top burning in the updraft gasifier and then with various burner port hole areas giving different flame velocities for various given fuel burning rates. Final burner design as shown in Figure 3.6 gave a steady burning of producer gas at the desired fuel burning rate of 10–15 kg/h

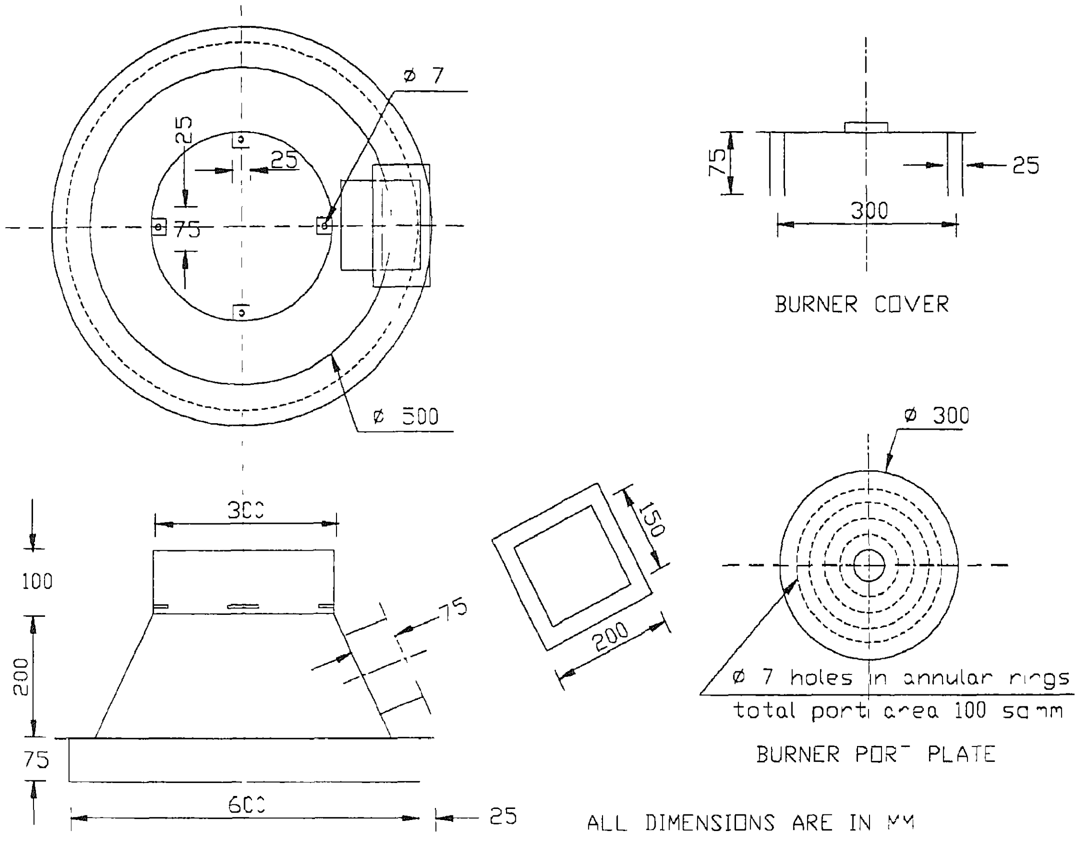


Figure 3.6. Producer gas burner design for gasifier-based large-cardamom dryer

During all the trial runs, emphasis was given to restrict the flame from reaching the cardamom as the sparks from the fire reaching the cardamom capsule bed in the final stage of drying can catch fire and destroy the whole produce Initially, a layer of pebbles on wire mesh was tried but it adds to cost Later, it was decided to put a small 2 ft × 2 ft perforated MS sheet at a distance of 1 to 1½ ft above burner to control the flame and its performance was found to be quite satisfactory and safe during trial runs at TERI

CHAPTER 4

Field testing at Kabi (North Sikkim)

After developing the prototype gasifier design at TERI and carrying out trials on its performance, it was decided to test it under the actual field conditions. Apart from providing field performance data, the field testing will also help in verifying the size of the system i.e. whether it would be sufficient to dry one batch (400-600 kg fresh cardamom) of crop and the time taken for the drying operation Field experience and feed back from the farmer would help in improvising the system design.

4.1 Preparation for field testing

Since there was little time left and as cardamom harvesting season has started already in Sikkim in the lower elevations, it was decided to carry the metallic burner part of the system and ACC castable supercrete insulating material from Delhi to Sikkim by train for making field prototypes of the gasifier.

On the way to Gangtok, a survey was carried out at Siliguri for availability of fabrication facilities It was found that all metal fabrication facilities are available but only small half barrel size *tandoor* was available It was told that making large 200 litre oil drum size *tandoor* will take 4–5 weeks time and it may break during transport from Siliguri to Sikkim due to bad road conditions Local insulating material, which is generally used in furnaces of surrounding tea industries, was quite cheap (Re 1 per kg), but its suitability for use in gasifier was doubtful Material transported by train was collected at Siliguri and taken to Gangtok by jeep

On reaching Gangtok, a meeting was held in ISPS for planning field testing activities Assistant Engineer from Department of Horticulture (who was deputed to assist TERI personnel throughout the field testing activity) also participated in the meeting

A visit was made to village Kabi which is about 18 km from Gangtok on north Sikkim Highway The field site was selected at Mr Kachung Bhutia's *bhatti* as he was known to be a progressive farmer in the area This *bhatti* was very close to road side adjacent to the Spices Board's Office Other advantages of this site were ease of transport, availability of electricity and shed The bhatti size was 2 5 m by 3 5 m which was a little larger than the average size of 2 m by 2 m observed during the earlier survey.

4.2 Fabrication and insulation of the system at Kabi

A survey was carried out in Gangtok for availability of hardware items and fabricators A used oil drum was purchased from an oil vending shop and given for modification to M/s Gurung

Traders Other fabrication items such as GI sheet duct, cylindrical mould for casting insulating material, grate, fuel feeding hopper-door, etc were fabricated in the workshop under the supervision of TERI staff All these fabricated items, along with castable insulation, and the burner were transported to the field site at Kabi Casting of insulating material in the drum was carried out at the site as per the procedure given by the supplier. Curing of casting with gradual heating took 3–4 days. Meanwhile the *bhatti* was modified and renovated In order to have a clear gap of 2–3 feet between burner top and wire mesh on which cardamom capsules are to be laid down, a 2 feet deep pit was made at the bottom of the *bhatti* as shown in Figure 4 1

Figure 4.1. Pit made inside the existing *bhatti* to accommodate gasifier system

After completion of curing the gasifier was installed inside the *bhatti* in the pit made and trial runs were started Wet wood logs of fresh cut tree were tried initially but since it gave some problem in obtaining consistent quality gas it was decided to go for dry cut wood pieces for gasifier operation as per the earlier plan Local labourers were hired on daily wages to cut the wood logs into 4–6" inch long pieces Wood was purchased from the owner and from other local suppliers

Earlier wood charging was done from a small side port and fire was ignited by using a small hand blower (Figure 4 2) In practice, the farmers can even use a hollow bamboo to blow air for ignition as is generally done in chulhas Later on, in order to take out the initial smoke

during ignition and during fuel charging, a one meter long duct was attached to the fuel input port of the gasifier (Figure 4 3) But this duct was getting blocked due to small wood pieces during fuel charging and removing blockage was consuming a lot of time In order to overcome this problem, fuel charging duct was again modified to a gun shaped duct consisting of two ducts, the short bottom duct for feeding fuel and top one for venting of smoke. Both ducts were interconnected from inside so that while fuel is being charged the flue gases can be vented through the top duct Now since the fuel charging duct is very short, feeding fuel inside the gasifier was quite easy and quick and very less smoke goes to the cardamom bed during fuel charging (Figure 4 4) Later on the gas outlet duct was extended so as to take out the smoke not only from below the cardamom bed but also from the entire *bhatti* shed

Figure 4.2. Gasifier system in operation during trial runs at Kabi

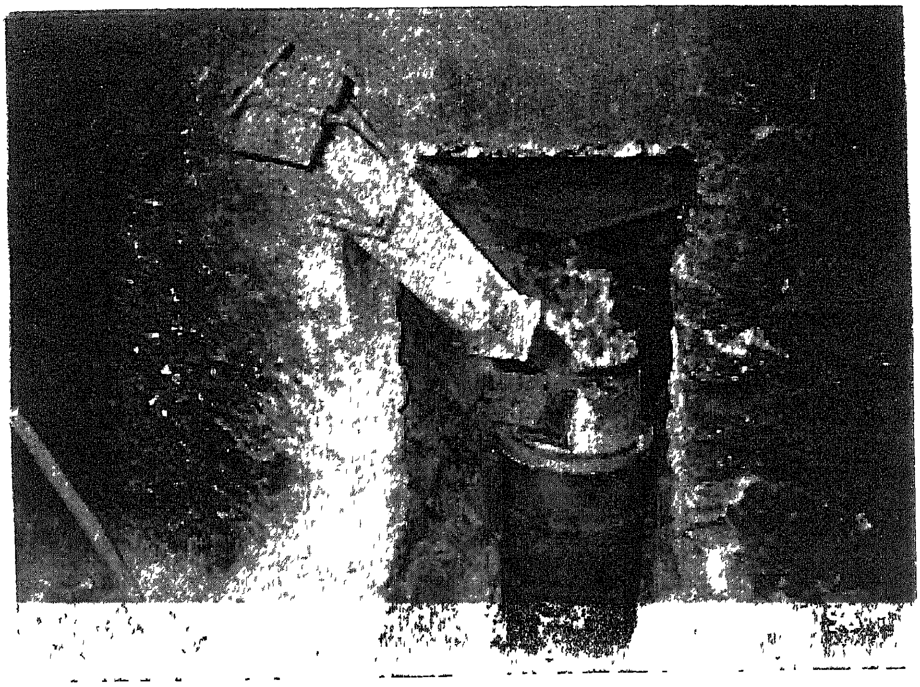


Figure 4.3. Duct attached to gasifier fuel inlet to take out the smoke

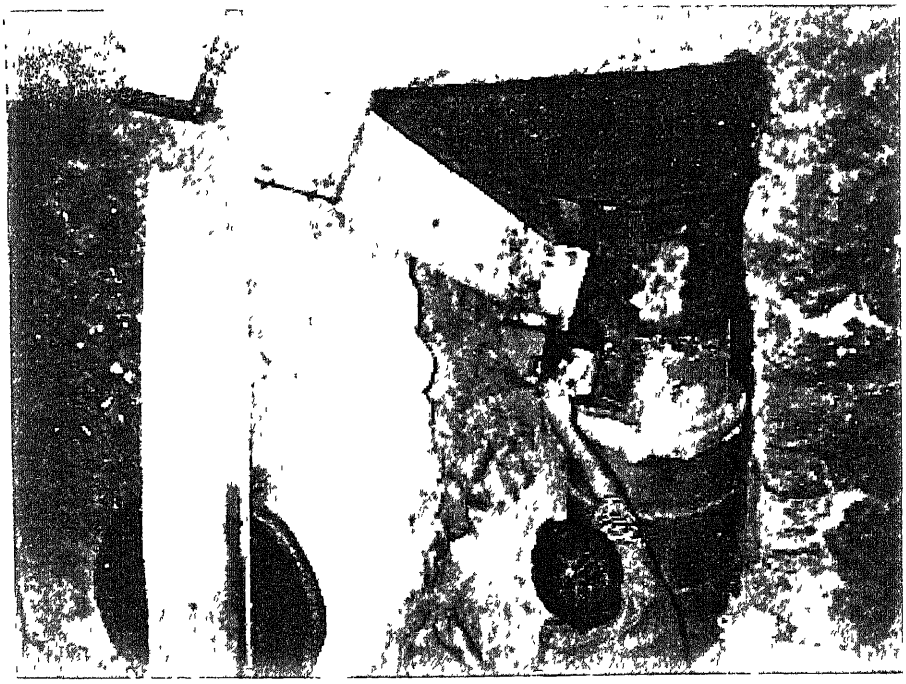


Figure 4.4. Modified fuel charging duct enabling quick fuel charging

4.3 Trial testing of the system for performance monitoring

For this purpose, totally five batches of large-cardamom were dried at the site Kabi, three batches at Mr Kachung Bhutia's *bhatti* and two batches at State Horticulture Department's farm.

4.3.1 Field testing in Mr Kachung Bhutia's bhatti

Batch-1: September 27–29, 1996

About 450 kg of fresh cardamom capsule was loaded and at the end of drying about 95 kg dry capsules were obtained. Unfortunately there was heavy and continuous rain on that day and no power was there for few days. During few hours of operation it was found that there is a need to increase the burner port area to obtain consistent and good quality flame. But since there was no power the required modification could be done only on the morning of 29th September After that, drying was completed on same day evening Therefore though it took long time to complete the drying due to these problems, the last day's improved and consistent operation of the system gave hope for reducing the drying time drastically in the subsequent trials.

Quality of the cardamom was not upto the expectation as there was lot of smoky operation during initial stages due to problems mentioned above. But there was definite reddish shade with an indication of improvement in quality Fuel consumption was about 10–12 kg/h after the modification of the system and consistently good quality flame was obtained The average fuel consumption was about 1 23 kg/kg fresh cardamom

Batch-2 October 4–5, 1996

The second batch operation was much better than the first one. For drying 550 kg fresh cardamom it took 33 hours and consumed only 355 kg of fuel wood About 122 kg dry capsules were obtained with good colour But it was felt that owner made hurry in removing the capsules (perhaps to avoid further weight loss about which farmers are more worried than quality of dried product and its storage life) and it could have been better if it was dried a little more

Batch-3 October 11, 1996

This was the batch dried during the field visit of officials from various organizations and also it was the batch in which the best performance was achieved during the field testing

Since by this time operation of the gasifier-based system was better understood, with a much higher confidence level, a visit of officials from various organization was arranged during this batch Dr Urs Heierli of SDC, New Delhi and Director as well as Secretary Horticulture (Government of Sikkim) made a visit to the site to see the gasifier-based system operating in the field. Officials from ISPS, Spices Board, State Horticulture Department and farmers were also present (Figure 4 5 to 4 6)

Figure 4.5. Field visit to gasifier-based large-cardamom dryer installed at Kabi

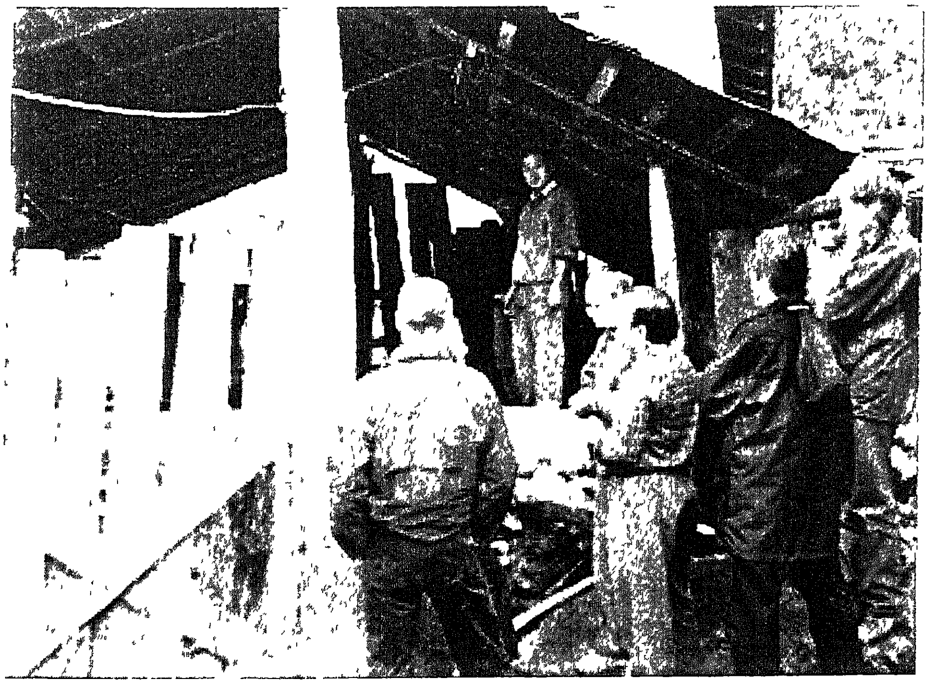


Figure 4.6. Field visit to gasifier-based large-cardamom dryer installed at Kabi

About 300 kg fresh cardamom capsules, brought from State Horticulture Department's farm at Kabi, were loaded at around 8 a m. in the morning and the drying was completed a little after midnight (01:00 hours of October 12) on the same day i e. in just 17 hours Even at the time of visit between 11.00 to 12:30 hours there were clear indications of faster drying as well as quality improvement. Continuous and clean burning of producer gas obtained by gasification of wood giving no smoke was well appreciated by all the visitors The quality of the dried sample was very good with clear reddish shade About 60 kg dry capsules were obtained at the end of drying indicating a little over-drying and fuel consumption was only 227 kg giving average specific fuel consumption value of 0 75 kg/kg fresh cardamom

Since best quality dry cardamom was obtained in this batch it was planned to keep it for test marketing, but this could not be done as the produce was disposed off by State Horticulture Farm immediately after drying

4.3.2 Field testing in State Horticulture Farm at Kabi

After October 11th the unit was shifted to the adjoining state horticulture farm for further field testing Here it was decided to try operating the system on very wet (fresh) wood. But since the gasifier was designed for operation on dry wood pieces, it gave smoky operation and inconsistent burning with wet wood As earlier, the *bhatti* was modified by digging a pit to accommodate the gasifier in it Here the *bhatti* was of 2 25 m × 2 25 m in size with bamboo mesh and was in open space It was covered temporarily with a tarpaulin shed (Figure 4 7).

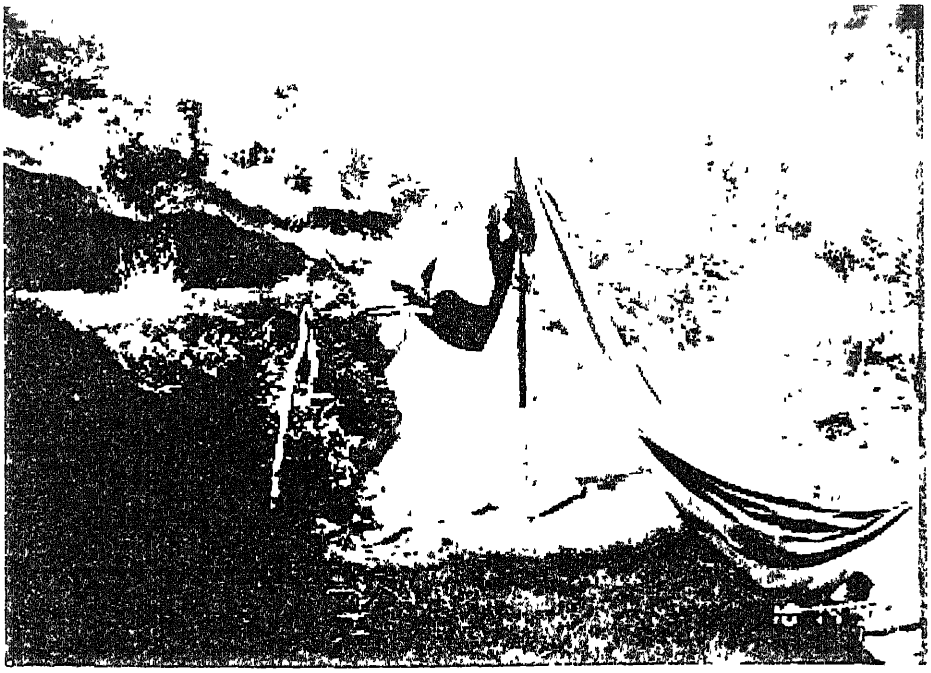


Figure 4.7. View showing *bhatti* with tarpaulin shed at Horticulture Farm, Kabi

By the time the gasifier was shifted uphill, one batch was finished already in the conventional *bhatti* at the State Horticulture Department farm It was told that for arranging fresh cardamom capsules for field visit extra labourers were hired and once harvesting is started all the crop was harvested in one go So it was decided to use the existing gasifier without modification (earlier plan was to construct new gasifier with local insulating material brought from Siliguri) as it was told that only limited amount of capsules for 1–2 batches were available on the farm. So it was decided to dry the ongoing batch of capsules by the traditional method of smoking In order to do this the burner part was removed and wood logs were burnt in the drum with open top Since this *bhatti* was having a bamboo mesh there was a fire hazard resulting in the loss of about 10 kg of capsules as sparks could reach the dry cardamom bed and caused fire This also proved the vulnerability of traditional *bhattis* to fire hazard

Afterwards another set of burners of both circular and square cross sections with removable burner plate were fabricated at M/s SSS Engineering Works, Tadong. Another gasifier was also fabricated with local insulating material but the material produced cracks in the insulation lining on curing (Figure 4 8) So it was not used for trials Ferrocement lining (lining cement or castable insulation on both side of wire mesh or bamboo mesh) type structure was also contemplated but the mason asked for Rs 2,000 just for labour charges which was exhorbitantly high Since other artisans could not be located by the TERI team, this idea was dropped due to shortage of time

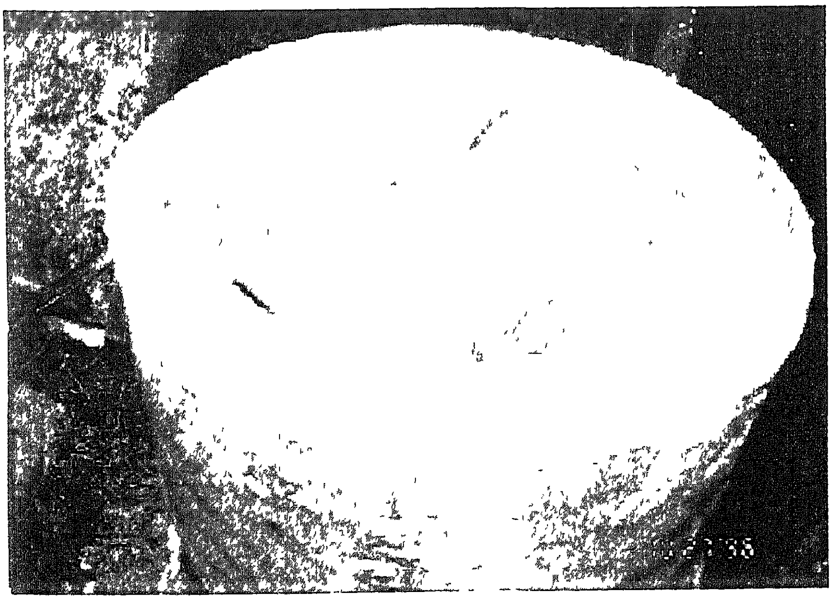


Figure 4.8. Cracks developed during curing of local fire clay insulating material

Since the best quality produce obtained from 3rd drying batch at Kachung Bhutia's *bhatti* was sold out by Horticulture Department there was not enough quantity of good quality capsules for trial test marketing In the project review meeting at ISPS it was therefore decided to purchase fresh cardamom capsules from farmers and dry it in gasifier-based *bhatti* to obtain about 100–200 kg capsules of good quality for test marketing As the harvesting season in the Kabi area was rapidly coming to an end, lot of difficulty was faced in obtaining dry wood and raw capsules locally Finally raw capsules for two drying batches could be obtained from the local *Sarpanch* Though these raw capsules were not of the best quality and were very fresh, it was decided to go ahead to try to obtain sufficient quantity of cardamom product from gasifier-based system So two more lots (4th & 5th) of capsules were purchased and dried in the gasifier-based *bhatti* at State Horticulture Farm using modified circular burner (Figure 4.9)

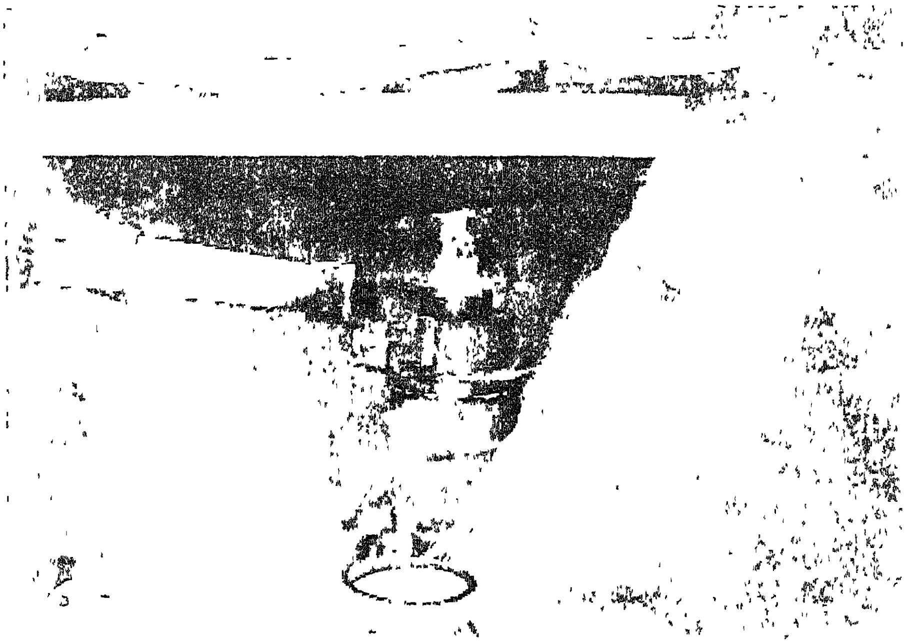


Figure 4.9. Modified circular burner installed at Kabi in operation

Batch-4: October 27–28, 1996

About 440 kg fresh cardamom capsules were loaded in the *bhatti* on 27th October at 4 pm and drying was completed in 24 hours About 111 kg dry produce with good colour was obtained Total fuel consumed was 229 kg in 24 hours for 440 kg fresh capsules which means average burning rate of 9 5 kg/h and specific fuel consumption of 0 5 kg/kg fresh cardamom

Batch-5: October 31–November 1, 1996

This time about 420 kg fresh cardamom capsules were loaded in the *bhatti* at 9.30 pm on October 31st The new square burner tried gave some problems initially with smoky operation So after midnight, the earlier circular burner was installed again to re-establish consistent burning of producer gas On completion of drying at 7 30 pm next day (in 22 hours) about 86 kg dry produce was obtained The colour of the dried cardamom obtained was not very good like the earlier two batches, the main reason may be poor quality capsules due to delay in drying after plucking and also initial smoky operation for few hours Drying of 420 kg fresh capsules was completed in 22 hours consuming about 195 kg fuelwood

At the end of fifth batch of drying, a rectangular burner (Figure 4 10) was used In this case, an attempt was made to keep the gasifier outside and burner inside the *bhatti* as this may help in quick fuel charging in the gasifier from top This will not only enable use of relatively larger pieces of wood but will make sure that smoke is outside *bhatti* during fuel ignition as well as during fuel charging, when smoke levels are generally high Though trials were quite successful, it was decided to optimize the idea further at TERI before trying it for the next year's field testing

Figure 4.10. Modified rectangular burner installed at Kabi in operation

The data collected during field testing is summarized in Table 4.1. It can be observed from the table that about 300–500 kg fresh cardamom capsules can be dried using the present prototype unit, which is the average capacity of traditional *bhatti* observed during survey. Specific fuel consumptions in the range of 0.5 to 0.8 kg fuelwood per kg fresh cardamom were achieved as compared to 1 to 3 kg fuelwood per kg fresh cardamom in traditional *bhatti*. These figures translate to fuel saving of the order of 50 to 60%. This may be due to reduced drying time and improved overall thermal efficiency of the order of 20–30% Apart from fuel saving the other major benefits observed during trial field testing include improved quality of cardamom. good natural reddish colour, higher volatile oil content and complete drying.

Table 4.1. Summary of gasifier system performance data during trial field testing at Kabi

Parameters	Batch number				
	1*	2	3	4	5
Initial weight of fresh cardamom capsules (kg)	450	550	300	440	420
Final weight of dried cardamom capsules (kg)	95	122	60	111	86
Total drying time (h)	45*	33	17	24	22
Total fuelwood consumed (kg)	553	355	227	229	195
Fuel burning rate (kg/h)	12.3	10.8	13.4	9.5	8.9
Specific fuel consumption (kg per kg fresh cardamom)	1.23	0.65	0.76	0.52	0.46
Specific fuel consumption (kg per kg dry cardamom)	5.82	2.91	3.78	2.06	2.27
Overall thermal efficiency (%)	10.7	20.2	17.7	24.0	28.6

* Approximate value for intermittent operation due to heavy rain and burner-grate modification

4.3.3 Quality analysis of cardamom dried in gasifier-based system at Kabi

The dried cardamom capsules, obtained from gasifier-based dryer system were tested for quality from Sri Ram Industrial Research Institute, New Delhi and the results are summarized in Table 4.2 for two important parameters such as moisture content and volatile oil content.

Table 4.2. Quality analysis of large-cardamom dried in gasifier-based dryer at Kabi

Sample details	Moisture (% by wt)	Volatile oil (% v/w)
Sample no 1 of batch 4	7 90	2 40
Sample no 2 of batch 4	8 30	2 40
Sample no 1 of batch 5	12 90	2 10
Sample no 2 of batch 5	11 20	2 30
Protocol followed	IS 1797	IS 1797
Quality standard General Grade*	14 0	1 0
Quality standard Limit Grade*	12 0	2 0

* see Annexure A of TERI Project Report dated April 1996[3]

It can be observed from the table that for all the 4 samples (of the capsules dried in gasifier-based system) the volatile oil content is even higher than limit grade quality standard of large-cardamom. It is apparent from the table that the grade is directly related to lower moisture content and higher oil content. This confirms that there is an improvement in quality of dry cardamom obtained from gasifier-based system in terms of both the quality parameters of oil content and moisture content

4.4 Technical issues raised during trial field testing at Kabi

Trial field testing proved the concept and indicated possibility of substantial improvement in quality and specific fuel consumption. However, the following issues came up during the course of field testing, which need attention

(a) Weight of the system

The main question regarding the weight of the system was whether the system should be light so that it can be transported from one *bhatti* to other as harvesting shifts from the bottom of the hill to the top during season or whether it should be considered as a permanent structural component of the *bhatti* i e one system for each *bhatti* Other questions were Even for marketing the system in future what should be the weight of the system? Should the insulation casting be done at a centralized place (by manufacturer) or at site?

(b) Wet or dry wood

In the present design of the gasifier-based system, dry wood is used as fuel In Sikkim, wet wood is used at present for cardamom drying and people have inertia to switch over to dry wood as it needs advanced planning to dry and store wood. However it should not be impossible, as it is a common practice in Sikkim to cut and store dry wood in piles for use in winter for heating and cooking.

(c) Use of wood chips against wood logs

In traditional *bhattis* big wood logs of fresh green trees are used, whereas in the gasifier wood chips of about 3" diameter and about 5–6" long are used. There is a feeling of additional labour cost associated with wood cutting in the case of gasifier. However it has been observed that there is a practice of cutting wood in about two feet length for making a pile and storing it for future use So if gasifier design can be modified to accept a little longer wood pieces (about 10–12") farmers can cut wood into this size while making the pile itself with some extra effort

These were the major issues which need to be addressed. In order to get answers to these it was decided to carry out a field survey to get the opinion of the farmers

4.5 Survey to assess the acceptability of gasifier-based dryer

As the trial field testing was limited to only one site and since some general issues as listed above came up during field testing, it was felt that discussions with cardamom farmers in other districts of the state would provide useful inputs for refining the design and for gauging the acceptability of the gasifier-based drying system Annexure 1 gives the list of farmers surveyed while Annexure 2 gives a copy of the questionnaire used for this purpose

4.5.1 Methodology

The survey conducted entailed questionnaire based interviews with both small and large farmers, and visits to sites of traditional *'bhattis'* in the field The farmers were shown photographs of TERI's gasifier and its operation was explained to them, along with the constraints and benefits of the new system Farmers interviewed were randomly selected to include both small and big holdings In all, 47 farmers were surveyed representing the four districts of the state, namely North, East, West and South. The benefits and constraints were ranked in order of preference by the respondents The rankings thus obtained were assigned values, and the average weighted values were calculated for respective constraints and benefits. The higher the value the more importance attached to the issue

4.5.2 Survey results

Constraints

The major constraints of the gasifier considered are

- Initial cost (Rs 2000) of the gasifier
- Needs dry wood (but 50% less)
- Needs cut wood (4" × 6" pieces)
- Gasifier too heavy (200 kg) for mobility

The reactions of the farmers to the constraints varied, but the overall consensus was that the weight of the gasifier posed a problem for its easy portability. This constraint was ranked first (weighted value of 15 3) by the majority This is followed by the difficulty in cutting the wood into small pieces (12 9 value); and the problem of collection and storage of dry wood (weighted value of 12). The initial cost of the gasifier (6.8 value) was viewed as the least of the constraints.

In Kabi area where the farmers observed the gasifier in operation, the main constraints according to them were drying the wood and cutting it into pieces before feeding However, farmers in other areas stated that collection of dry wood would not be so difficult as the households had to store wood for cooking purposes in any case, and using the improved gasifier would entail only storage of larger amounts

With regard to the portability of the gasifier, farmers with *bhattis* close to roads have no objection with the weight of the gasifier But those with large number of *bhattis*, and at different altitude levels had reservations Carrying the gasifier along steep foot tracks would be a tedious task, and the risk of damaging the lining of the drum great. According to them a weight of 80–100 kg should be suitable But concern was expressed by most farmers about the life of the gasifier They said that a reduction in weight should not compromise the life and the capacity of the gasifier It was also opined that the existing capacity of the gasifier could be enhanced

For most farmers the price of the gasifier is not a constraint if the performance is satisfactory, though some marginal farmers expressed their reservation regarding the price. But the large farmers can easily afford it

Benefits

The likely benefits of improved *bhatti* considered are

- 50% fuel saving
- Better quality of product
- Less time for drying
- Lower labour due to lower fuel consumption

The farmers are unanimous in the view that less fuel consumption (15.6 weighted value) is the main advantage of the gasifier. This is attributed to high cost of firewood (Rs 350–400 for a pile of 50 cu ft) Lower labour input owing to less fuel consumption is the third best merit of the gasifier (11 3 value) But it was also felt that lower labour input may be offset by engaging labour to cut the firewood into smaller size. For the farmers, reduction in fuel consumption will bring about savings, in light of woody biomass scarcity in the state.

Better quality product (12 4 value) is yet another advantage according to them. Better colour will fetch about Rs 5 more per kg of dried cardamom in the market. While this was more applicable to big farmers, for some farmers, the colour did not matter. According to them the traders are bothered only about the dryness of the product, irrespective of colour.

The reduction in drying time is of least significance (7 7 value) to the farmers, as it offers no substantial advantage over traditional *bhattis* For a number of them, the feeding of larger quantities of wood in the traditional *bhattis* would expedite the drying process.

The results of the survey giving ranking of various constraints and benefits of gasifier-based dryer system as perceived by the farmers are summarized in Table 4 3

Table 4.3. Results of the survey to assess acceptability of gasifier-based dryer

Issues (constraints/benefits)	Ranking (average weighted value)
Constraints	
Initial cost of gasifier	6 8
Needs dry wood (but 50% less)	12 0
Needs cut wood (4" x 6" pieces)	12 9
Gasifier too heavy for mobility	15 3
Benefits	
50% fuel saving	15 6
Better quality product	12 4
Less time for drying	7 7
Lower labour due to lower fuel consumption	11 3

In principle the improved model appealed to the farmers, especially the benefits of fuel savings and higher monetary returns due to better quality of the product However, they were skeptical of introduction of new methods of drying cardamom probably due to failure of earlier attempts made by Spices Board and others With regard to the constraints in dissemination, farmers prefer a portable system, but so long it does not jeopardize the drying capacity and life of the gasifier Further, according to the farmers, the problem of dry wood procurement could be tackled, and the cost of the system was of least concern in view of the benefits

CHAPTER 5

Development of improved prototype unit

5.1 Review of feedback through field testing at Kabi

During the field testing at Kabi and experience gained through it, the following factors were found to be worth considering in order to improve the system design and its operation to make it more user friendly and acceptable.

- the location of gasifier inside the *bhatti* causes exposure of smoke to cardamom bed specially during fuel charging and sometimes during unstable flame operation at the start.
- though the duct helps in taking the smoke out of the *bhatti*, it makes fuel charging difficult as the duct is narrow and long. Even after modifying the duct at Kabi, the problem of charging small wood pieces is not solved satisfactorily.
- a person has to go inside the *bhatti* to charge wood pieces into the gasifier and in case of flame extinguision there is a possibility of exposure to smoke This was felt more critical as producer gas contains CO (carbon monoxide).
- in the 1st prototype unit the entire casting was done in-situ and weighed more than 150 kg making the system very bulky This makes it difficult to transport the system from one place to another The survey conducted by TERI staff indicated that many farmers did not bother about the weight of system and were ready to accept it as permanent part of civil construction like *bhatti* But if the system has to be manufactured at a centralized place, then the transportability of the system would be an essential requirement for its installation, especially in remote farms where motorable approach road is not available.
- there was inherent resistance of farmers to use dry wood and that too after cutting it into small pieces

5.2 Modifications made in system design

In the light of the above points, several modifications were made in the system design to make it more user friendly These are described below in detail

5.2.1 System configuration

Configuration of the system layout is changed by keeping the gasifier out of the *bhatti* and taking the producer gas inside through a duct to the burner located below the cardamom bed as shown in Figure 5 1 This helps in several ways.

- The smoke is kept away from the *bhatti* and hence its contact with cardamom capsules is avoided, thereby improving the scope of retaining better colour.

- Gives scope for improving fuel charging component of the system to make it more easy to operate and acceptable for larger size wood pieces
- Provides option for the farmer to enlarge the gasifier size if desired in the future.

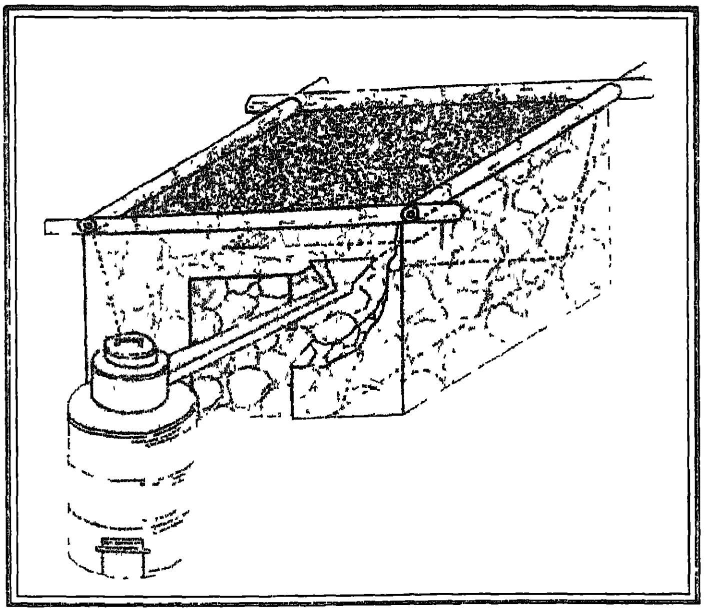


Figure 5.1. Modified system layout with gasifier outside and burner inside the *bhatti*

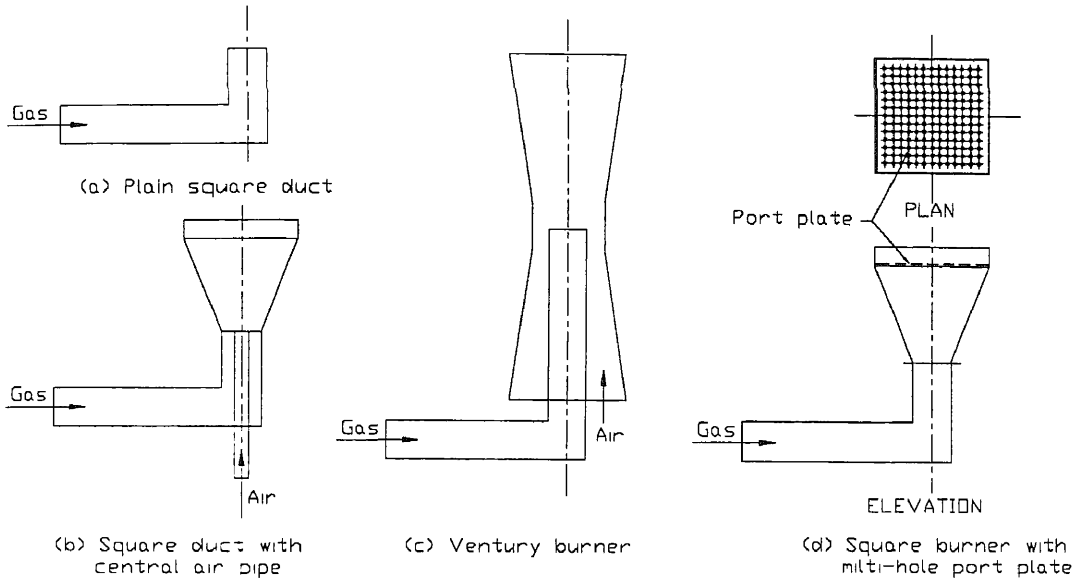
5.2.2 Producer gas burner design

Several trials were made at TERI in order to see whether wet wood can be used in the present size gasifier unit Though producer gas could be obtained with fresh *safeda* wood (commonly available in Delhi) the duration of stable operation of flame was very short The main reason seems to be the difficulty in maintaining high temperatures (of the order of ~ 1000°C) necessary for reduction reactions of gasification with addition of fresh wet wood Therefore, it was decided to stick to use of dry wood and to concentrate on the possibility of using larger size wood pieces

Various burner designs tried with dry fuel wood pieces included·

- Simple square duct
- Single square open burner with central air pipe
- Venturi burner
- Square burner with multiple small ports

Figure 5 2 shows the schematic diagram of various burners tried at TERI's Gual Pahari campus



(a) Plain square duct

(b) Square duct with central air pipe

(c) Ventury burner

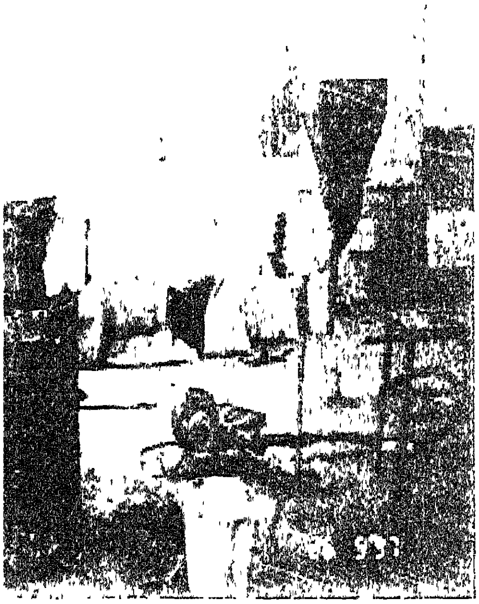
(d) Square burner with milti-hole port plate

Figure 5.2. Schematic diagram of various burners tried at TERI's Gual Pahari campus

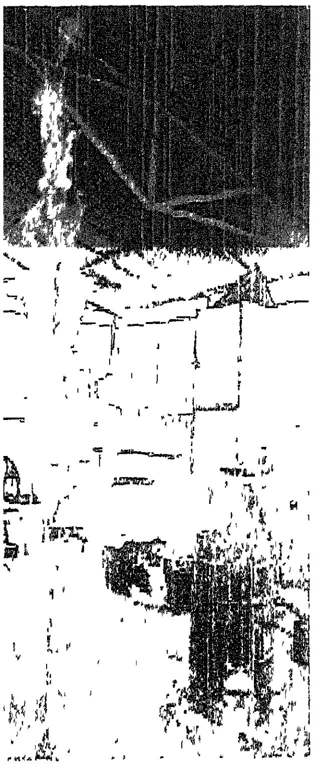
The first option gives very high burning rates, probably due to low resistance for fluid flow and a little inconsistent flame It is worth mentioning here that burner design is a little tricky as producer gas is a mixture of two main constituents, namely hydrogen (H_2) and carbon monoxide (CO) which fall on two opposite sides if flame speeds are compared. Hydrogen has very high flame speed, making it explosive in nature, while carbon monoxide has very low flame speed.

In another attempt a small air pipe was placed at the centre of an open square burner as shown, but it still gave inconsistent and smoky burning as shown in Figure 5.3

The venturi burner allows for good mixing of gas and primary air. Its varying cross-sectional area along the length gives advantage of flame stability as location of flame gets adjusted at a cross-section depending on the prevailing gas quality (proportion of CO and H_2) Thus venturi burner can take care of some variation in gas composition while giving stable flame. The only drawback of venturi burner is the tall height required which forced us to drop this design for application in cardamom drying. Also it gives very long (tall) flame as shown in Figure 5 4, necessitating a large gap between the burner and cardamom bed in order to avoid the possibility of fire hazard



and inconsistent burning with small air pipe at the
e burner



ire 5.4. Gasifier operation with
uri burner

Therefore, it was decided to go ahead with the square burner with a plate having multiple ports. Through several trial runs the number of holes and total port area was arrived at for a given system layout (burner located at about 2-3 meter away from gasifier) and the desired fuel burning rates of 10-15 kg/h. Figure 5.5 gives a schematic diagram of the square burner with multi-hole burner port plate. Figure 5.6 shows a close-up of the square burner.

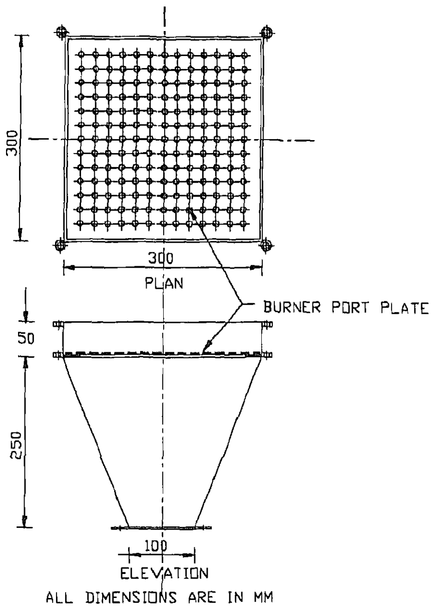


Figure 5.5. Schematic diagram of the square burner with multihole burner port plate

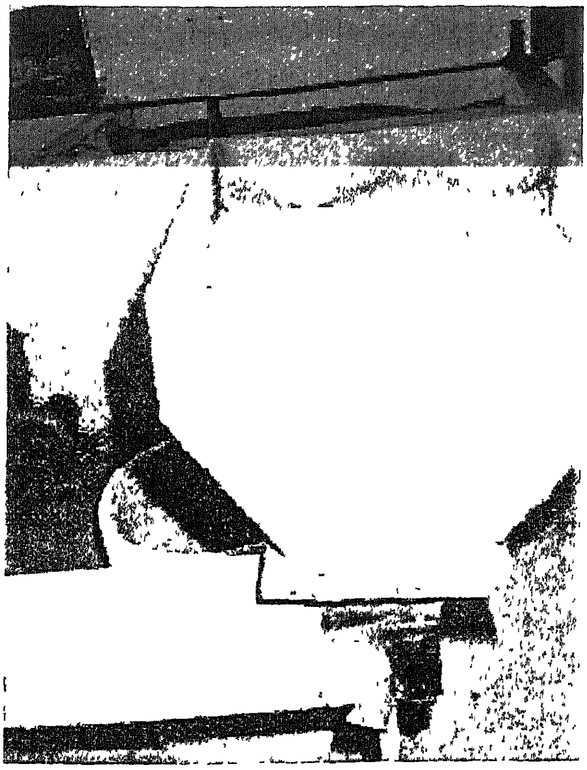


Figure 5.6. Close-up of the square burner

5.2.3 Fuel charging mechanism

In developing fuel charging mechanism the emphasis was to·

- to make it easy and quick to operate
- to enable use of larger size wood pieces

Initially gasifier cover with wide rectangular opening on the top was tried which enables charging little longer wood pieces (Figure 5 7) In order to make hopper door gas tight three levers were provided on the three sides with hinge on the fourth side

Though this design allowed use of longer wood pieces, closing the door with three levers was little cumbersome

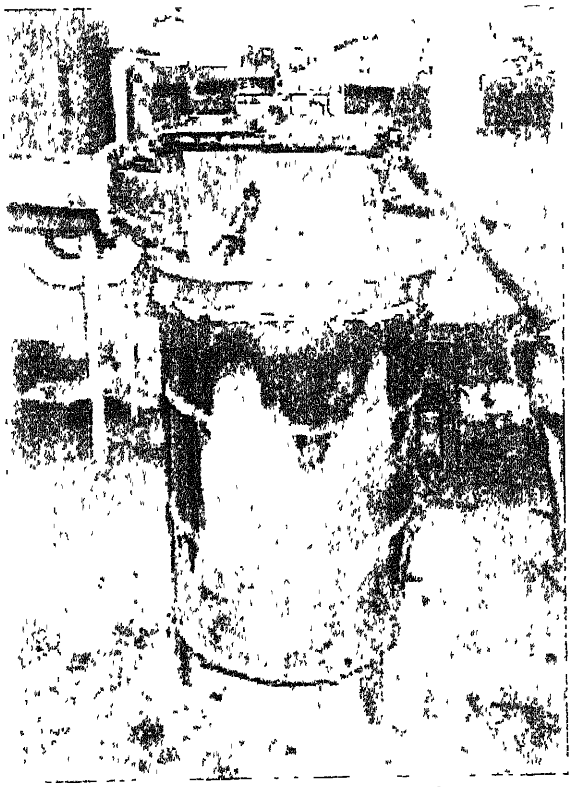


Figure 5.7. Gasifier cover with top rectangular opening for fuel charging

Accordingly the system design was modified with 12 × 12" square door which can be operated and closed with a simple lever mechanism A schematic diagram of the fuel charging mechanism is shown in Figure 5 8 The system can now take large wood pieces up to 10-12" long as against 4-6" in the earlier prototype design. Thus, as for domestic use, farmers can make piles of dry cut wood of 10-12" length (presently they do it with 1½ feet length). No extra cutting will then be required, if this is done while making the pile itself with a little extra effort in cutting wet wood in shorter logs

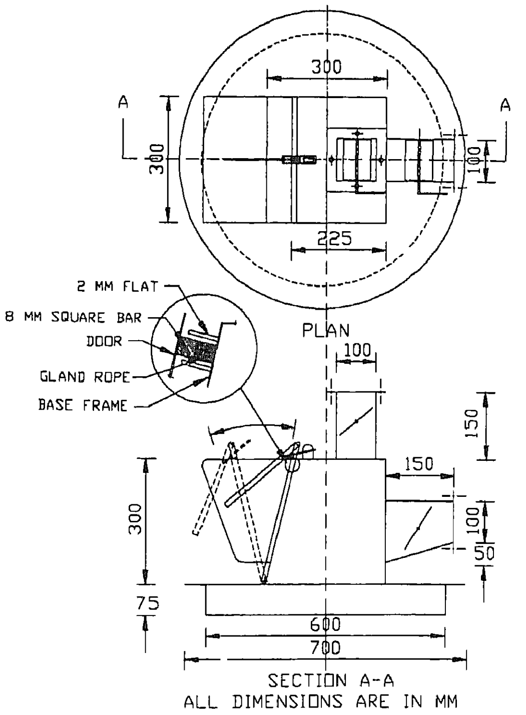


Figure 5.8. Schematic diagram of gasifier top cover with fuel charging lever mechanism

In the improved system the operator need not open screws of fuel charging door. He has to just use a lever to open and close it. On opening the door it gets converted into a hopper shape making fuel charging quite easy and fast (Figure 5.9). Valves (dampers) are provided in

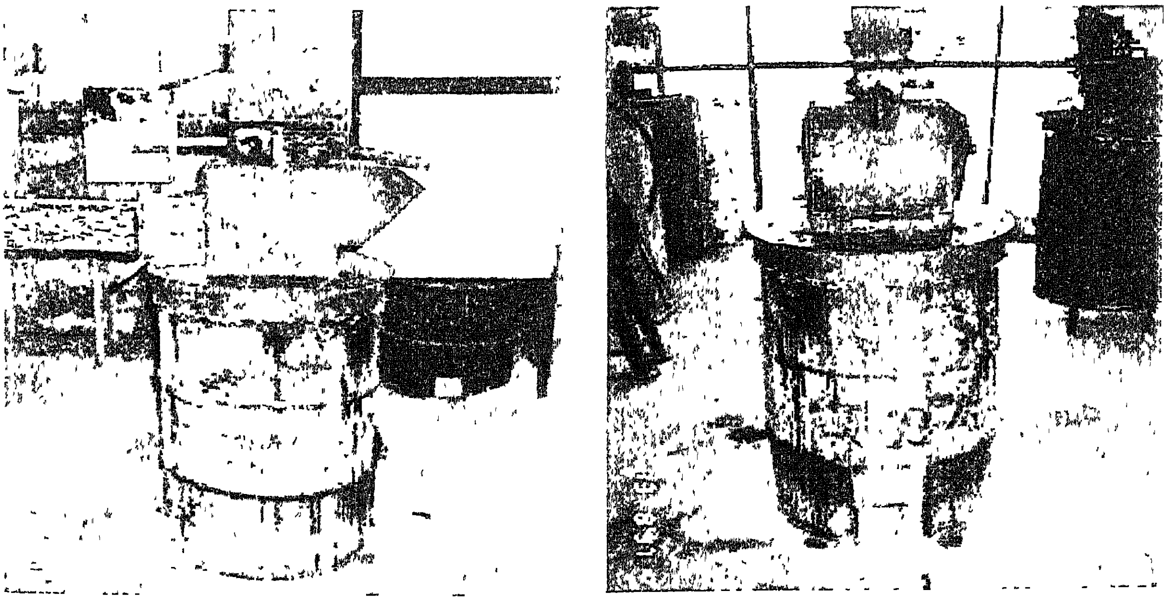


Figure 5.9. Gasifier cover with fuel charging hopper

the duct to keep the gas away from cardamom bed carrying the gas to the burner and in the entrance to the chimney During charging or during ignition, the operator has to just close the gas outlet valve and open the top chimney valve so as to keep the gas away from cardamom bed.

5.2.4 Gasifier insulation

In the earlier prototype, gasifier insulation was done in-situ using castable firecrete insulation material and so the entire insulation becomes an integral part of gasifier (oil barrel) making it bulky and heavy for transportation. Also there was suggestion by people in Sikkim to use local or near local material for gasifier insulation. The objectives of developmental efforts, therefore, were oriented

- to use low cost insulating material to reduce system cost
- to minimize the system weight in order to make it transportable.
- to see if local material such as clay can be used.

Several grades of castable insulation were tried in the gasifier and finally ordinary grade firecrete insulating material which withstands about 1200°C and costs around Rs 9 per kg was chosen for insulating the gasifier In the earlier prototype, ACC Supercrete Whyteheat brand material, which withstands up to 1650°C and costing Rs 21 per kg was used. This would help in reducing cost of insulation by about 50%

In order to make the system transportable it was decided to make the insulation in 2 or 3 castable rings of 1" to 1½" thickness This would make the weight of each individual insulation ring within transportable limit (See Figure 5 10).

At TERI's Gual Pahari campus attempts were made to divide the castable insulation into three rings in which insulation thickness was reduced gradually from bottom ring to top ring from 1½" to ½" (See Figure 5 11). Though this works fine and substantially reduces the weight and cost, it was decided to make 2 rings of uniform 1" thickness (with inner diameter of about 50 mm) for convenience sake Thus farmers can keep one or two spare insulation rings, if required, as now it is of uniform thickness and still the weight of each individual ring is within the transportable limit.

In order to give an option to farmers for use of local material, mud/fire clay rings were tried as an insulating material for gasifier These rings were got constructed by a local *tandoor* making shop in Delhi and tried in the gasifier (See Figure 5 12). It works quite satisfactorily as far as gasifier performance is considered, indicating that it is a viable option. The only difficulty in adopting it in practice is the care needed in its transportation Being made of clay, the rings are brittle and shocks in transportation, specially on bad interior hilly roads of Sikkim may cause cracks

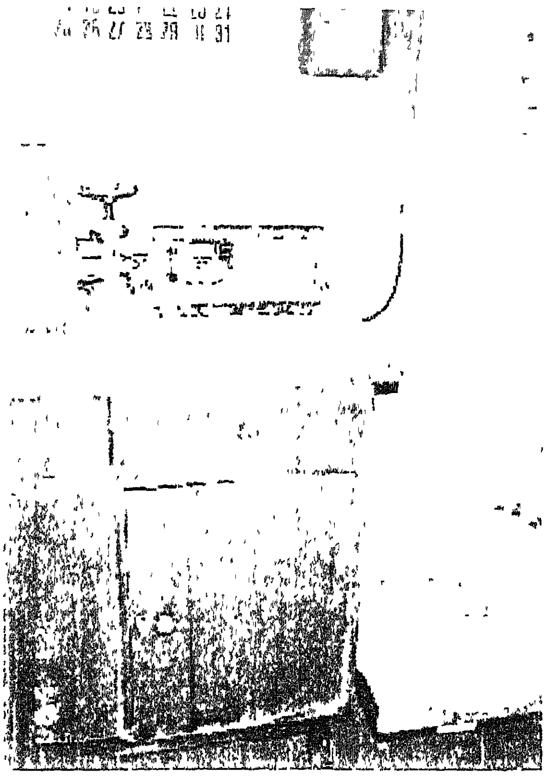


Figure 5.10. Individual castable insulation ring weighing within transportable limit

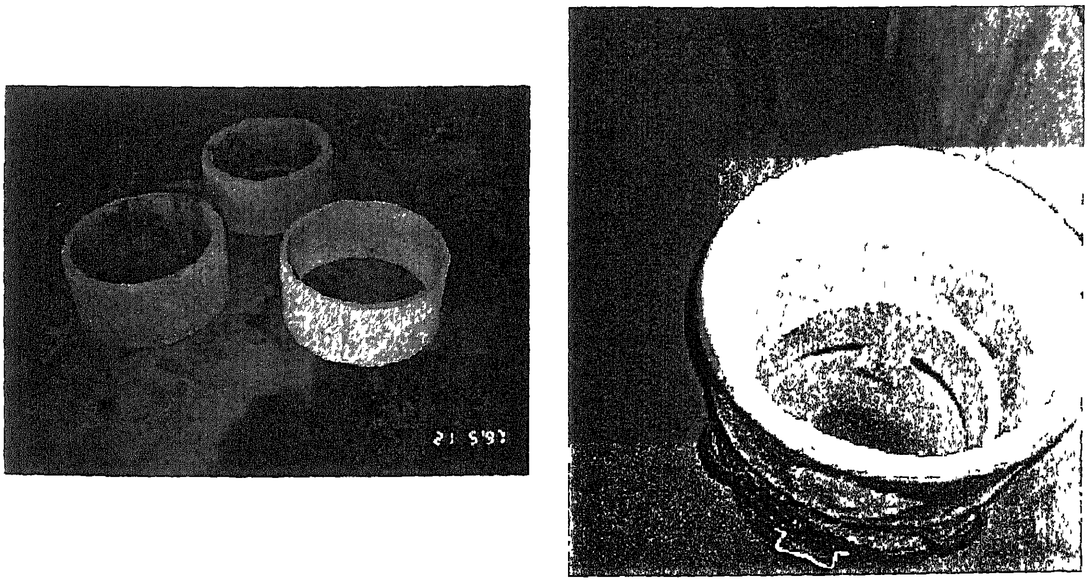


Figure 5.11. Insulation rings with gradually reducing thickness from bottom to top

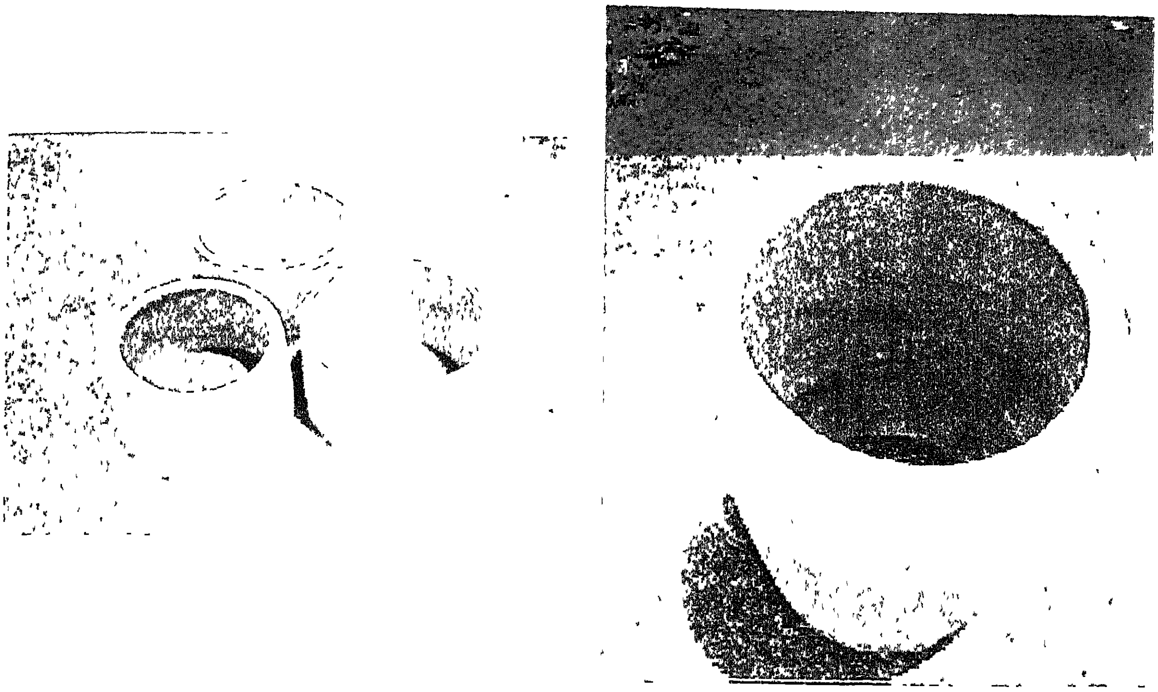


Figure 5.12. Mud/fire clay rings tried as an insulation for gasifier

The final configuration of the gasifier-based system arrived at for its extended field testing in all four districts of Sikkim consisted of the following parts.

1 Used oil barrel (with air inlet port at bottom)

2 Castable insulation rings (casting at the base of barrel and two precast rings of 1½" thickness)

3 Fuel charging hopper with lever mechanism (dampers in gas outlet and chimney).

4 Mild steel grate

5. Gas carrying duct

6 Square burner with multi-hole burner plate

7 Perforated sheet for flame height control

8 Spacer rod to hold flame arrester above the burner

9 Chimney duct with end cover.

Figure 5 13 Shows the cut-sectional view of the entire assembly of gasifier-burner assembly which can be used as an add-on attachment to any existing traditional *bhatti* system (see also Figure 5 1 which shows a schematic of the gasifier system installed in an existing *bhatti* structure) The critical distances required to be maintained (e g gaps between burner, flame arrestor and cardamom bed) are also indicated in Figure 5.13

In order to understand how all the individual components will have to be assembled in the field, a detailed exploded view is given in Figure 5 14

CHAPTER 6

Planning for extended field testing of improved prototype unit

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A tour was undertaken by TERI staff in order to plan and make arrangements for smooth conduct of extended field testing as this time it has to be at four different locations, one each in all four districts of Sikkim The objectives of this preparatory tour were.

- to identify progressive farmers for field testing site.
- to make agreement with farmers for smooth conducting of field testing
- to identify suitable workshop for fabrication of the systems in Sikkim

6.1 Selection of field testing sites

With co-operation of Principal Scientific Officer (Spices) deputed by Horticulture Department, Government of Sikkim to assist TERI staff in executing field activities in Sikkim, the following sites were selected for extended field testing in all four districts of Sikkim during the cardamom harvesting season of 1997

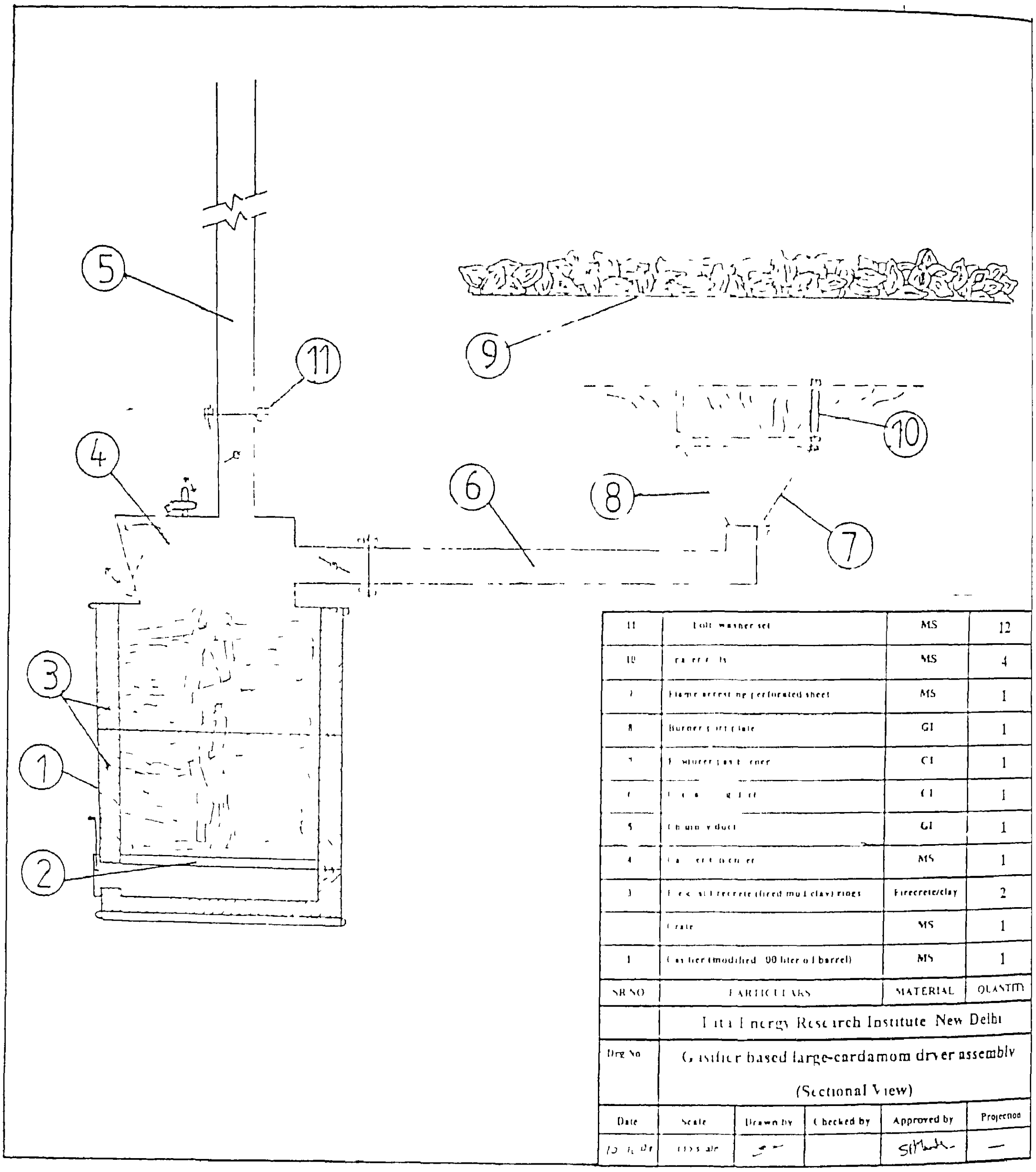
- Mr Ambiraman Rai, Assam Lingzey (East Sikkim)
- Mr Ongay Topden, Ravangala (South Sikkim)
- Mr I B Gurung, Kaluk (West Sikkim)
- Mr P G Tenzing, Mangan (North Sikkim)

Field visits to east and south Sikkim sites were undertaken for collecting information on existing traditional *bhatti* through a dialogue with the farmer and by making measurements of the geometry of the *bhatti*.

However visits could not be undertaken to the other two sites in west and north Sikkim as Mr I B. Gurung was in Gangtok and the road to north Sikkim was bad for field visit However, owners of these sites were contacted in Gangtok and detailed discussions were held to clarify all relevant points in arriving at formal agreements in which both assured full support and co-operation.

6.2 Agreement with farmers selected for carrying out field testing

In order to ensure smooth conduct of field tests at all selected sites, formal agreements were made between TERI and farmers with Horticulture Department and ISPS as witness to these agreements The salient features of the agreement are as follows



SR NO	PARTICULARS	MATERIAL	QUANTITY
11	Bolt washer set	MS	12
10	[illegible]	MS	4
9	Flame arresting perforated sheet	MS	1
8	Burner port plate	GI	1
7	Burner [illegible] cover	GI	1
6	[illegible]	GI	1
5	Chimney duct	GI	1
4	[illegible]	MS	1
3	Fire [illegible] firecrete (fired mud clay) rings	Firecrete/clay	2
	Grate	MS	1
1	Gasifier (modified 200 liter oil barrel)	MS	1

Tata Energy Research Institute New Delhi

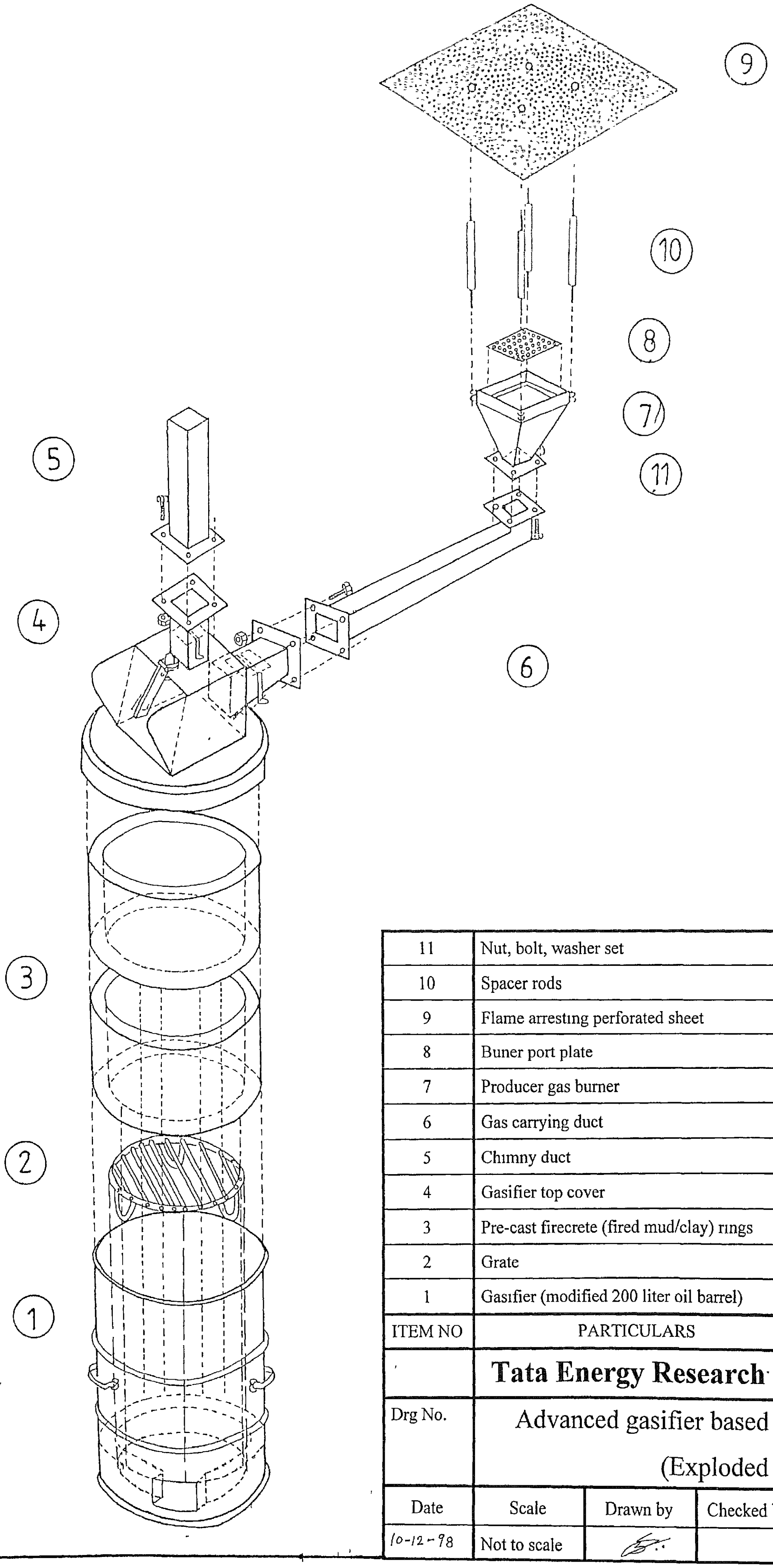
Drg No

Gasifier based large-cardamom dryer assembly

(Sectional View)

Date	Scale	Drawn by	Checked by	Approved by	Projection
[illegible]	[illegible]			[illegible]	—

Figure 5.13. Cut-sectional view of gasifier-burner assembly



11	Nut, bolt, washer set	MS	12
10	Spacer rods	MS	4
9	Flame arresting perforated sheet	MS	1
8	Buner port plate	GI	1
7	Producer gas burner	GI	1
6	Gas carrying duct	GI	1
5	Chimny duct	GI	1
4	Gasifier top cover	MS	1
3	Pre-cast firecrete (fired mud/clay) rings	Firecrete/clay	2
2	Grate	MS	1
1	Gasifier (modified 200 liter oil barrel)	MS	1
ITEM NO	PARTICULARS	MATERIAL	QUANTITY

Tata Energy Research Institute, NewDelhi

Drg No.

Advanced gasifier based large-cardaom dryer
(Exploded View)

Date	Scale	Drawn by	Checked by	Approved by	Projection
10-12-98	Not to scale				—

TERI offers

- to provide and to install the advanced gasifier-based dryer system in the field and to dry the produce so as to obtain about 300-400 kg of good quality dry large-cardamom.
- to supervise the installation and commissioning of the system along with modifications in the existing *bhatti*.
- to supervise and help local *bhatti* operator to dry the large-cardamom in the modified gasifier-based system
- to assure purchase of about 300 to 400 kg of good quality dry capsules (from the total dry capsules obtained) dried in the gasifier-based system at the rate of Rs 100 per kg dry cardamom

Owner of the bhatti agrees to offer following facilities to TERI

- Supply dry cut firewood (size of each cut piece· 3 to 4 inch in diameter and 7 to 9 inch long) in sufficient quantity (conservative estimate of about 1.5 to 2 tonnes) in order to dry at least 4 to 5 batches. This will be done well in advance (at least 4 weeks) before actual commencement of 1st batch of drying. Wood required for trial operation of the system for its fine tuning before actual drying of cardamom will also be provided to TERI free of cost
- Modify the existing *bhatti* as per instructions of TERI professionals so as to install the gasifier-based dryer system The manpower and local civil material required to carry out the modification will be provided by the farmer In carrying out the modification TERI professionals will try to minimize changes in the existing *bhatti*.
- Provide the manpower (a) to shift the system component from nearest approachable road point to actual *bhatti*, (b) to carry out modification in the *bhatti*, (c) to install the system at site, (d) to operate the system for drying cardamom using the gasifier-based system. This will also help in turn to train the local personnel to operate the system in future.
- Provide other facilities such as (a) shed over *bhatti* (preferably permanent but at least temporary), (b) temporary electricity connection from nearest point (this will help TERI in carrying out on-the-spot system modifications, if needed, and also in operating instruments for performance monitoring), (c) assistance in getting accommodation and food at the site during field testing, the expenses for which will be borne by TERI.
- Allow TERI professionals to dry the cardamom capsules as per their quality requirement of moisture content
- Sell about 300 to 400 kg of good quality dry cardamom capsules, dried in gasifier-based system, to TERI at the rate of Rs 100 kg per kg of dry cardamom

6.3 Identification of manufacturer

A survey of various fabrication workshops in and around Gangtok was carried out to see the facilities available with them for manufacturing/fabricating the gasifier system. M/s Figu Engineering Works, Ranipool was finally chosen to do this job. The system fabrication details, componentwise, were explained to him with the help of sketches and photographs He also showed interest in making castable insulating rings at his workshop by making moulds for the same.

6.4 Fabrication of the improved prototype units in Sikkim

One model set of fuel charging device and producer gas burner was fabricated at New Delhi and transported to M/s Figu Engineering Works by train along with castable firecrete material Two sets of system components were fabricated in the workshop at Ranipool under supervision of TERI's staff, during which the fabricator gained experience and confidence and fabricated the remaining systems on his own.

For making castable insulating rings two circular MS moulds were fabricated and all the insulating material rings were fabricated in association with the technical staff of TERI For one system, tested at Mangan, the insulating material used was that purchased from the ACC dealer in Siliguri

CHAPTER 7

Extended field testing of the improved prototype

7.1 Field testing at Assam Lingzey (East Sikkim)

Being in southern part of Sikkim and at a relatively low altitude, harvesting at this site was expected to start first i e by the end of August But due to delayed rains and changed weather conditions in Sikkim, harvesting period got delayed and the 1st batch could be dried only from 29th September The gasifier system was installed well in advance after carrying out minor repair work of the *bhatti* such as blocking leakage for gas through the stone walls of the *bhatti*, replacing bamboo mat with wiremesh, providing a temporary shed over the gasifier for demonstration purpose, and covering the front opening of the existing *bhatti* with bamboo mat door to minimize heat losses Figure 7 1 shows the gasifier system installed at Assam Lingzey.

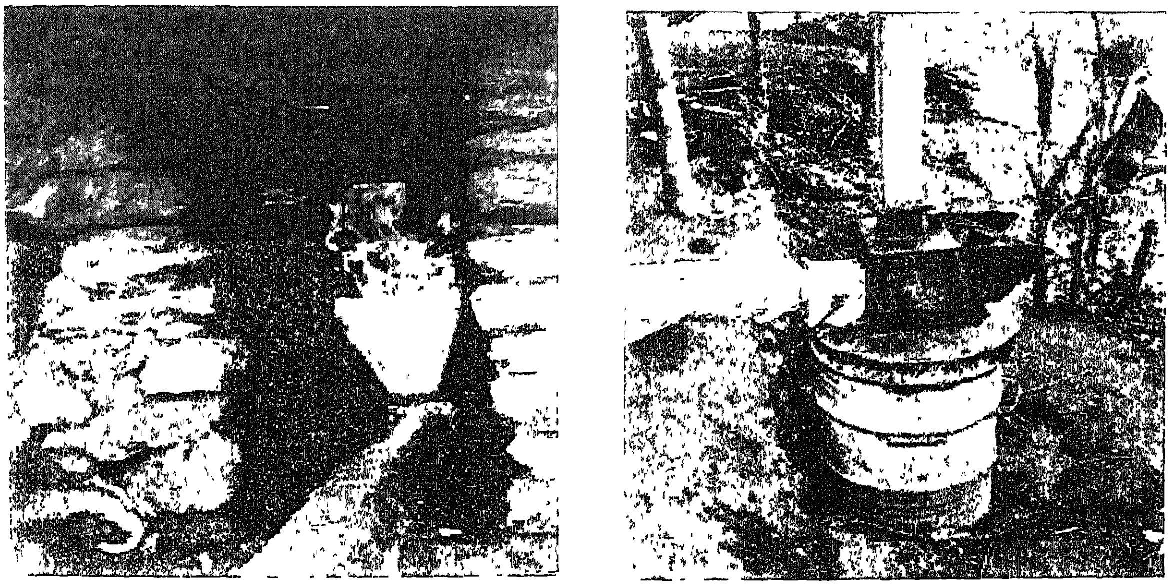


Figure 7.1. Gasifier system installed at Assam Lingzey (East Sikkim)

A total of four batches were dried here in the presence of TERI staff. During the field testing, the owner got the feeling that the new system consumed more fuel, but later on he was convinced about the fuel saving by actual fuel measurement The fact that the farmer operated the gasifier system for the remaining batches by engaging labourers for wood cutting gave proof of acceptability of the system The summary of field testing data at Assam Lingzey for the four batches dried is given in Table 7.1.

Table 7.1. Assam Lingzey (East Sikkim): summary of field testing data

Batch No	Date	Quantity of fresh capsules (kg)	Quantity of dry capsules (kg)	Drying time (h)	Total fuel consumed (kg)	Specific fuel consumption (kg per kg of fresh cardamom)
1	29-30 Sep 97	422	86 5	24	310	0 73
2	03-04 Oct 97	600	135	32	311	0 52
3	07-08 Oct 97	455	105	23	192	0 42
4	08-09 Nov 97	580	126	31	210	0 36

7.2 Field testing at Kaluk (West Sikkim)

Here the expected harvesting time was from middle of September. But as mentioned earlier due to delayed harvesting season this year, the owner sent a message that it will start only after 15th of November However, the actual harvesting started by the end of October This was probably due to some communication gap from the farm level to the owner. As soon as TERI team got the information, the system components were transported from the workshop in Ranipool to the field testing site at Kaluk within a day or two and system was made operational on 11th November The first batch was started on 11th November itself. Since the crop was harvested more than a week before actual drying started, the capsules were pre-dried (which is also clear from the high ratio of dry to wet weight of capsules) at the time of starting of drying operation The variety of capsule here was small (*chhota dana*) cardamom The newly made *bhatti* was also wet and during the first batch, part of heat could have been used to drive out the moisture from the *bhatti* structure The drying of all harvested crop was completed in two drying batches, the performance data for which is given in Table 7.2.

Table 7.2. Kaluk (West Sikkim) summary of field testing data

Batch No	Date	Quantity of fresh capsules (kg)	Quantity of dry capsules (kg)	Drying time (h)	Fuel consumed (kg)	Specific fuel consumption (kg per kg of fresh cardamom)
1	11-12 Nov 97	351	107	20	162	0 46
2	12-13 Nov 97	273	114	15	128	0 47

7.3 Field testing at Ravangala (South Sikkim)

At this site, the harvesting was more or less as per expected time span i.e. middle of November. Unfortunately, due to unforeseen and unexpected health problems which occurred in the farmer's family, he was not available at the time of commissioning of the system which caused a lot of problems during the installation of system Dry cut wood had to be arranged afresh, as the already cut dry wood got soaked in rain due to absence of the owner. But on return of the owner everything went smooth and the owner personally took a lot of interest in operating the gasifier system on his own There was a lot of smoke in the first batch operation and partly in the second batch too, due to use of very wet wood. In the absence of dry wood, wet wood had to be dried first before using it in the gasifier, but partial drying of wet wood gave inconsistent gasifier operation. Once the farmer made arrangements for dry cut wood, the system performed very well from the third batch onwards Photograph in Figure 7.2 shows gasifier system in operation at Ravangala. The summary of field performance data of Ravangala unit is given in Table 7 3.

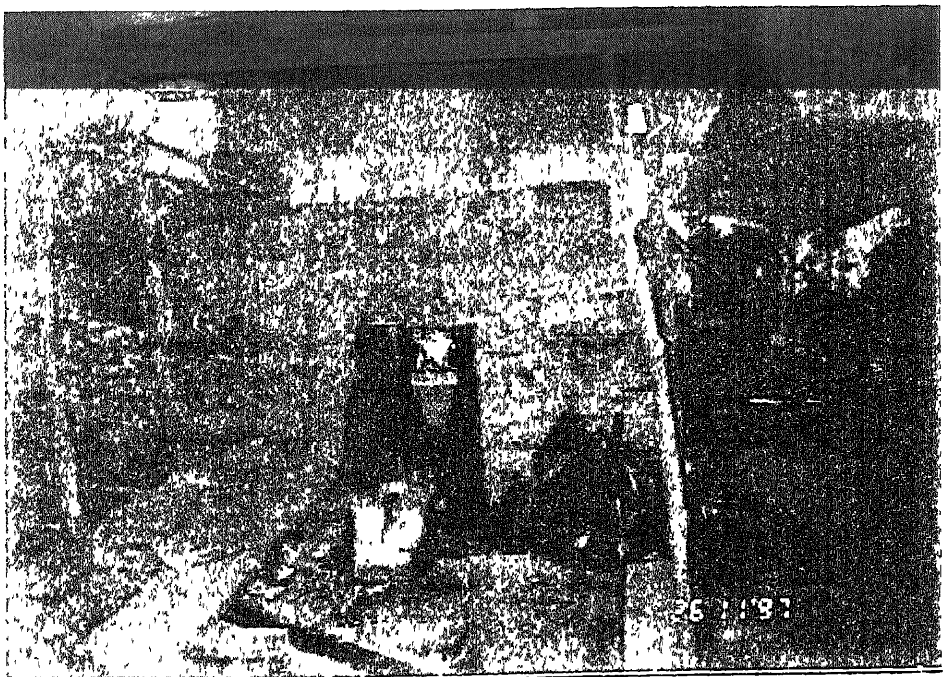


Figure 7.2. Gasifier system in operation at Ravangala (South Sikkim)

Table 7.3. Ravangala (South Sikkim): summary of field testing data

Batch No	Date	Quantity of fresh capsules (kg)	Quantity of dry capsules (kg)	Drying time (h)	Fuel consumed (kg)	Specific fuel consumption (kg per kg of fresh cardamom)
1	17-18 Nov 97	490	94	25	239	0 49
2	19-20 Nov 97	650	126	31	273	0 42
3	23-24 Nov 97	590	114 5	30	313	0 53
4	25-26 Nov 97	625	140 5	24	217	0 35
5	27-28 Nov 97	600	135	30	286	0 48
6	28-29 Nov 97	350	84	21	170	0 49

From Table 7.3, it can be seen that the *bhatti* at Ravangala is well constructed and properly oriented. Hence it gives better performance (as observed in the earlier study in which comparative performance evaluation of various traditional *bhattis* was done) compared to other traditional *bhattis* Specific fuel consumptions as low as 0.35 kg/kg fresh cardamom were obtained. Quality of dried cardamom was also better due to bold variety of capsules which were well matured.

7.4 Mangan (North Sikkim)

As decided in the meeting held on 18th September 1998 in Krishi Bhawan, on recommendation by Spices Board, one system was given to Mr C T Kazi, Member of AILCGA (All India Large-cardamom Growers Association). But after receiving the system components, the team was informed that he will not be operating the system this year as he could not arrange for dry wood.

In Mangan one system was installed in the field of Mr P G Tenzing at Manul Mangan (See Figure 7.3) The site was not far from the road, but quite steeply down the hill. Installation of the gasifier system at this site also strongly proved the transportability of the improved system, as the system could be easily taken down the hill and installed by farm level staff under the instructions of TERI staff within half day. A total of three batches of drying were carried out in the field unit. For the entire duration of field testing in the middle of a dense forest/cardamom field, TERI staff had to stay in a portable tourist tent which was a unique experience in itself (Figure 7.4). This also created a lot of enthusiasm and interest in operators who took keen interest in getting trained on installation, dismantling and reassembling, as well as in the operation of gasifier system

Figure 7.3. Gasifier system being installed at Manul, Mangan (North Sikkim)

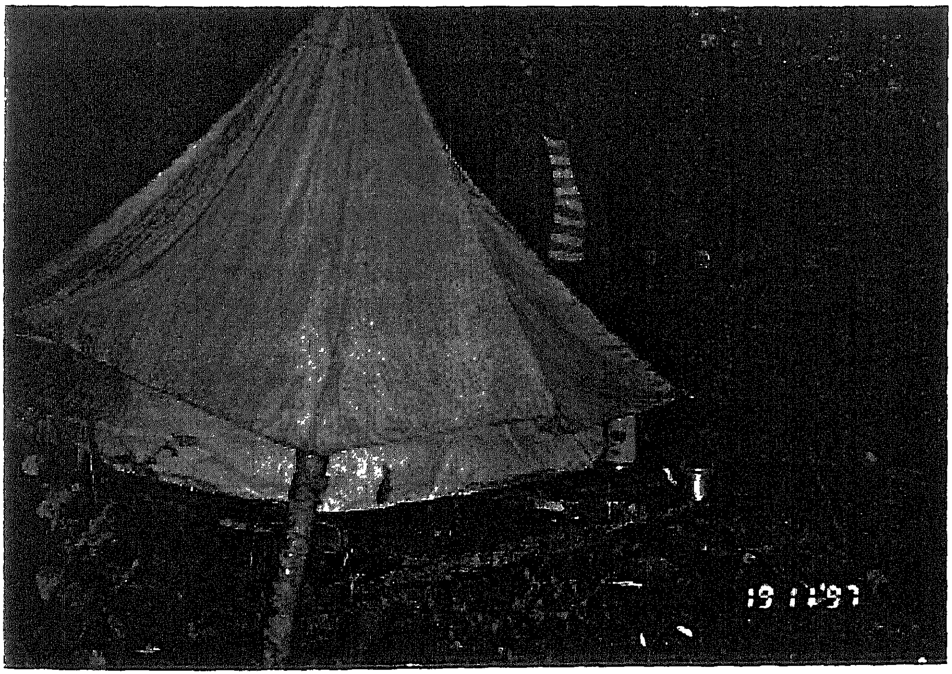


Figure 7.4. Portable tourist tent installed at Manul, Mangan for round the clock performance monitoring of the system

Initially the operators tried to use wet wood due to shortage of dry wood stock (as already dried wood stock was consumed elsewhere by local people) which gave inconsistent and smoky operation and took relatively longer time to dry the cardamom capsules. Poor construction quality of the existing *bhatti* with considerable heat losses due to leakages could have contributed to the relatively longer drying time experienced here.

During the 3rd batch of drying, an experiment was done by washing the capsules before drying, in order to see whether it helps further in improving the cardamom quality or not. It was observed that there was not much improvement in the quality due to such washing. In fact it resulted in a much longer drying time

After completion of three batches in the field, the system was dismantled and brought to Pantok, Mangan and was reassembled in an existing *bhatti* near Mr Tenzing's house to dry the remaining batches of cardamom from his other fields Photograph in Figure 7 5 shows the gasifier system re-installed at Pantok Mangan Here one more batch was dried under TERI's supervision and later on the gasifier system was handed over to the local *bhatti* operators who operated it successfully for the remaining batches Operators also took keen interest in recording data for other drying batches also. The data for seven drying batches (out of total 12 batches) is summarized in Table 7 4

Figure 7.5. Gasifier system re-installed at Pantok, Mangan (North Sikkim)

Table 7.4. Mangan (North Sikkim): summary of field testing data

Batch No	Date	Quantity of fresh capsules (kg)	Quantity of dry capsules (kg)	Drying time (h)	Fuel consumed (kg)	Specific fuel consumption (kg per kg of fresh cardamom)
In *bhatti* at Manul, Mangan						
1	15-16 Nov 97	524	113	29	395	0 75
2	17-18 Nov 97	492	102	24	484	0 98
3	18-20 Nov 97	495	102	33	447	0 90
In *bhatti* at Pantok, Mangan						
4	21-22 Nov 97	516	113	28	248	0 48
5	23-24 Nov 97	531	120	27	260	0 49
6	25-26 Nov 97	522	111	29	249	0 48
7	27-28 Nov 97	548	114	30	283	0 52

It can be observed from the data that the *bhatti* structure plays an important role in thermal performance The *bhatti* at Pantok, Mangan which was comparatively well constructed gave almost 50% less specific fuel consumption figures compared to those of the *bhatti* installed in the field at Manul, Mangan. The other reason could be the use of dry wood at Pantok which gave quite consistent and stable flame without giving any operational problem Operators were quite happy with the system here, as they have to just charge the fuel once in 1-2 hours and need not do any more work for maintaining the fire as required in traditional *bhattis*

As per one of the suggestions which came during the field visit, a simple multi-burner system, consisting of five small burners (one at the centre and four in the corners) instead of single large burner was fabricated in the workshop at Rampool (See Figure 7.6). It was then installed at Pantok, Mangan for the last few batches. The new system was successfully operated by TERI staff for 6-7 hours continuous operation (See Figure 7.7) to prove its efficacy to the operators and also to train them Later on they operated the system on their own. More uniform drying, requiring less reshuffling of cardamom bed resulting in 2-3 hours saving in drying time seems to be the major advantages of the multi-burner system. But before adopting this system in the long run the multi-burner system will have to be optimized (port area etc.) for reliable long duration operation

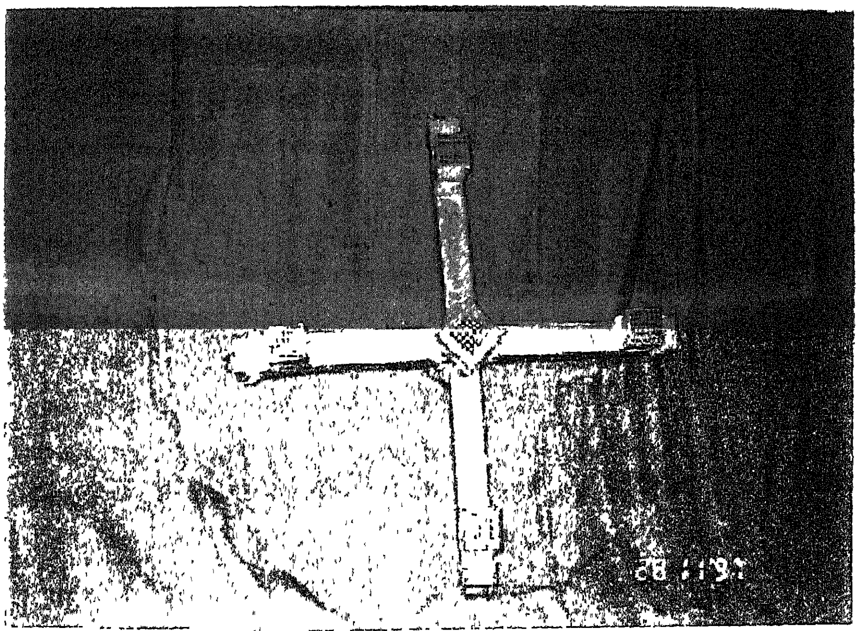


Figure 7.6. Multiburner system fabricated in workshop at Rampool

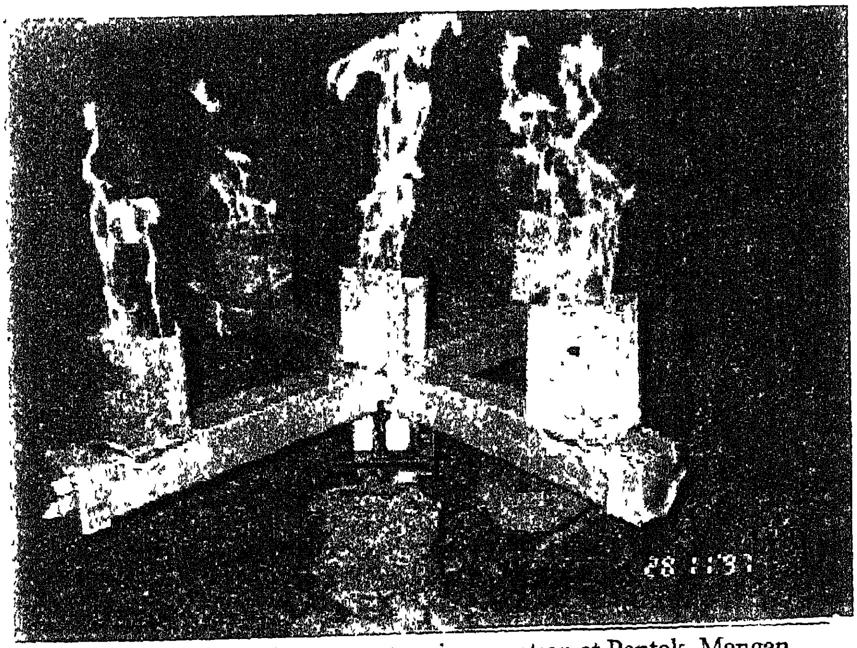


Figure 7.7. Multiburner system in operation at Pantok, Mangan

7.5 Demonstration of improved gasifier dryer system in Sikkim

During the field testing at all the four test sites, lot of farmers from neighbouring areas came to see the gasifier in operation. All of them appreciated the simplicity and ease of operation of the system as well as the improved quality of dried capsules. Many farmers showed interest in installing such a system in their farm in future and a few of them were even ready to purchase it after seeing the benefits of fuel saving and quality improvement.

Apart from this, other occasions that gave significant demonstration effect of improved gasifier-based cardamom dryer system in Sikkim included.

- Project review meeting on 18 September 1997 at Krishi Bhawan organized by Secretary, Horticulture Department. Here TERI gave a presentation giving a detailed account of its R&D efforts in development of the advanced gasifier-based dryer system, starting from performance analysis of traditional *bhattis* till development of the present improved transportable design. All system components were also displayed to participants who were from various organizations associated with cardamom drying in Sikkim and representatives of AILCGA. Mud clay insulation rings were also kept on display.
- On 3rd October 1997, a field visit was organized at Assam Lingzey (East Sikkim) for officials from various states and central government departments as well as organizations associated with large-cardamom development in Sikkim (Figure 7 8 and 7 9) The interior off-the-road location of the site proved the transportability of system in remote hilly regions of Sikkim (Figure 7.10).
- Officials from Spices Board, Cochin head office visited the Assam Lingzey site on 15th October 1997. During this visit, the owner was operating the system on his own voluntarily which proved the acceptability of the system by the farmer
- On 23rd October 1997, a Bhutanese delegation consisting of several scientists and officials associated with agriculture and large-cardamom curing program in Bhutan visited Assam Lingzey site and saw the gasifier system in operation. They were quite impressed by the system developed as it will have large potential in Bhutan also
- Officials from ISPS and SDC's Bangalore office visited field testing site at Ravangala (South Sikkim) on 26th November 1997 to see the gasifier-based system in operation (Figure 7.11)
- At Pantok, Mangan the system got wide demonstration effect as it was in operation during the district Panchayat President election Many Government officials, Panchayat heads, and farmers visited the field testing site at Pantok, Mangan to see the gasifier in operation They could see both single and multi-burner systems in operation and were quite impressed by the simplicity and quality improvement capability of the gasifier system.

Figure 7.8. Field visit of state and central government officials at Assam Lingzey

Figure 7.9. Field visit of state and central government officials at Assam Lingzey

Figure 7.10. Individual system component can be transported easily in hilly areas using bamboo baskets

Figure 7.11. Field visit of SDC and ISPS officials at Ravangala

- Director (Horticulture) visited the field testing site at Pantok, Mangan on 6th December 1997 to see the gasifier-based multiburner system in operation (Figure 7.12).
- The district collector (North Sikkim), State Ministers from North Sikkim, President of AILCGA District Panchayat President, and Sub-divisional Magistrate were among the few important personalities who have seen the gasifier system in operation at Pantok, Mangan and appreciated its performance (Figure 7.13).

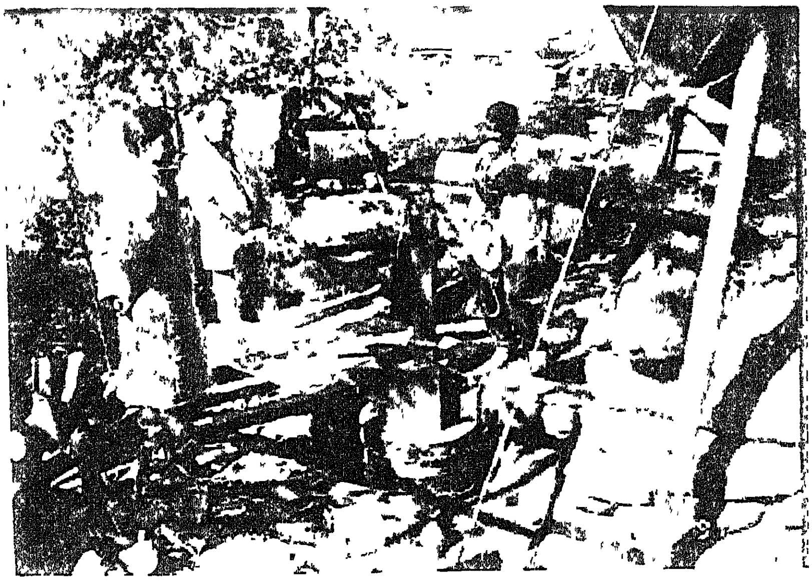


Figure 7.12. Visit of Director Horticulture Department to gasifier system installed at Pantok, Mangan

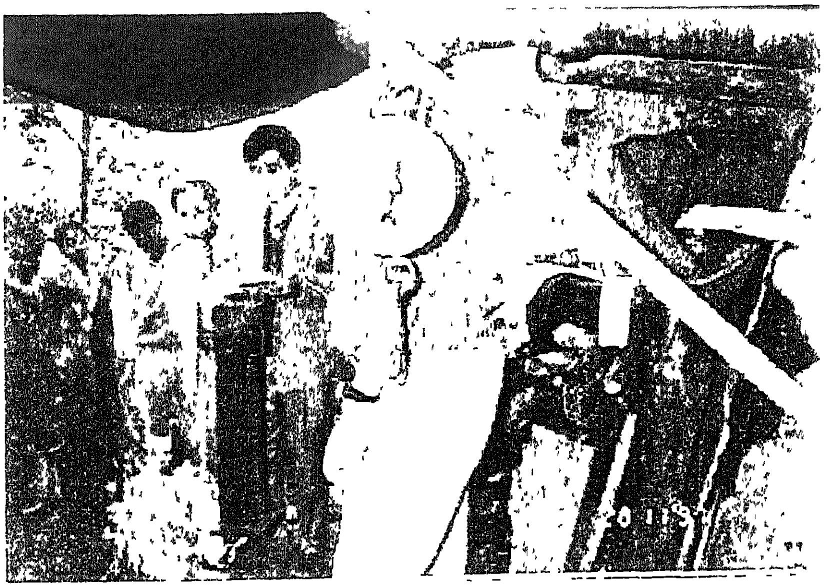


Figure 7.13. Visit of District Collector and SDM (North Sikkim) to gasifier system installed at Pantok, Mangan

CHAPTER 8

Quality analysis of cardamom

One of the major objectives of the alternate system development was to improve the quality of dried large-cardamom, apart from fuel saving through improved thermal performance. This was thought to be the most attractive benefit of the whole development project since there is a potential to improve the earnings of the farmers due to the possible premium the improved quality of the cardamom may fetch Also, achieving improved quality may boost exports of Indian cardamom giving an edge over the main competitors from Bhutan and Nepal

When cardamom samples obtained through trial field testing of the gasifier-based system at Kabi were analyzed for quality comparison it was proved that gasifier system can give uniformly well dried cardamom. At the same time it gave an indication that apart from improving the appearance (by retaining its natural reddish colour) cardamom dried in the gasifier-based system retains more volatile oil content too, which is responsible for its unique aroma Therefore, in order to verify this, the emphasis was on getting reliable and consistent data on quality improvement in respect of volatile oil content measurement for all the sites where field testing was undertaken

8.1 Importance of volatile oil content of large-cardamom

Volatile oil content in the large-cardamom gives a pleasant aromatic odour, due to which it is extensively used for flavouring vegetables and food preparations in Indian and *mughlai* dishes. It is also used as an essential ingredient in the preparation of mixed spices. Apart from aroma, large-cardamom also has high medicinal value. The decoction of seeds is used for gargling in infection of teeth and gums. Large-cardamom seeds are considered as an antidote to snake venom and scorpion venom[2] It is also reported that large-cardamom seeds are used as preventive as well as curative measure for throat troubles, congestion of lungs, inflammation of eyelids, digestive disorders and in the treatment of pulmonary tuberculosis[4,5] All these indicate that there are many important chemicals in the large-cardamom seeds which need to be retained during the drying/curing process.

Volatile oil present in the seeds of large-cardamom is one of the principle constituents for providing typical characteristic flavour and medicinal value. According to analysis of oil composition, the oil of *golsey* (locally called as *bada dana*) variety of large-cardamom, which consists about 50% of whole production and generally grown in the high altitude areas of north Sikkim, can be a substitute for small or green (*Elettaria Cardamomum Maton*) cardamom oil[6]. Presently there is no practice of extracting and selling the oil of large-cardamom due to its poor

quality (very less volatile oil content and burnt smell), whereas oil extracted from small cardamom is sold at a price of about Rs 8000 per liter[7]

This section describes the comparative quality analysis of dried cardamom obtained from gasifier-based system versus that obtained from traditional *bhatti* system

8.2 Experimental setup and procedure

Cardamom samples obtained from gasifier-based drying system and from the traditional *bhatti* system were tested for moisture and volatile oil content as per Indian standard IS 1797-1985.

Figure 8 1 shows the photograph of one set of Dean and Stark apparatus installed for quality analysis (measurement of moisture and volatile oil content) of large-cardamom in TERI's laboratory at Gual Pahari

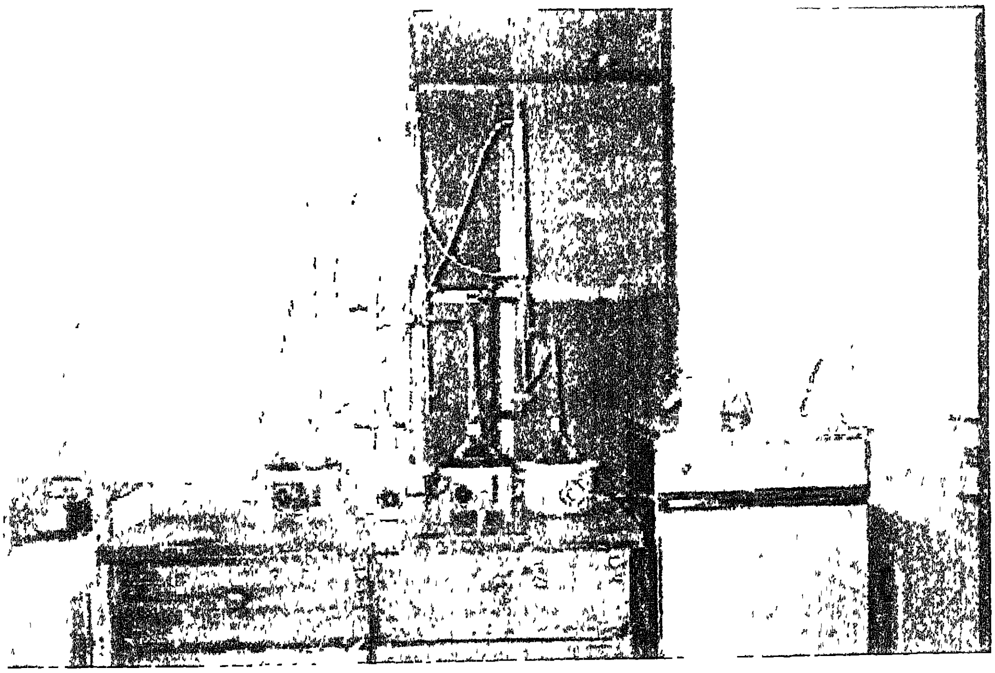


Figure 8.1. Dean and Stark apparatus installed in TERI's laboratory at Gual Pahari for quality analysis of large-cardamom

Moisture content

Figure 8.2 shows the distillation apparatus for moisture content determination of large-cardamom. It consists of a heating mantle, flask, receiver and reflux condenser. For sample preparation, all extraneous matter (both organic and inorganic) are removed manually Cardamom capsules are cut into 2-3 pieces in order to speed up the process and complete extraction of moisture. A known amount of the prepared sample (approximately 20-40 gm) is

taken so that moisture collected at the end of the process does not exceed the graduated portion of the receiver i.e. 10 ml. The weighed sample is put into the flask and about 200 ml of toluene is poured into it which is sufficient to soak all the capsules fully. Toluene was selected as the solvent because it is immiscible with water and has a lower boiling point of 80°C. A few glass beads were added in order to prevent bumping during the extraction process. After fixing the receiver and reflux condenser as shown in the figure, continuous cold water supply is given to the condenser. The flask is slowly heated and maintained to 80°C so that the extraction rate is approximately 100-150 drops per minute. The process is continued till the moisture level in the receiver remains constant for an hour The receiver is left at room temperature for about 2-3 hours or in cold water for about 15-30 minutes for complete separation of two immiscible layers of moisture and toluene Since moisture is heavier than toluene, the lower layer represents the moisture content which is reported in terms of ml/100gm or as percentage

Volatile oil content

A schematic diagram of the apparatus used for volatile oil determination is shown in Figure 8.3. The sample preparation for oil determination is same as for moisture determination. Approximately 100 gm of sample was taken to get a yield of 2-4 ml of volatile oil Water was used as a solvent for oil extraction Refluxing was done for 8-10 hrs to get a constant value. Since cardamom oil is lighter than water, it can be seen as a separate yellow layer on top of the water. Constant value for an hour represents complete extraction which was represented as percentage (%) volatile oil.

8.3 Results of the quality analysis experiments

The summary of the comparative quality analysis data of large-cardamom obtained from traditional as well as from TERI's gasifier-based system are shown in Table 8.1 and detailed measurements are compiled for all data points in Annexure 3 From the data given in Table 8.1 it can be concluded that there is a significant (above 35%) increase in volatile oil content in cardamom obtained from the gasifier-based system, which is in the range of 2.1 to 2.4% as against that of 1 7% observed in cardamom obtained from traditional *bhatti* system. Apart from this quantitative improvement there is a definite qualitative improvement in the oil extracted, in the sense that the oil from the improved cardamom had a clean and good smell whereas the oil from traditional cardamom was tainted with the smell of char

Presently there is no practice of extracting oil from large-cardamom, probably due to its burnt smell The advanced gasifier-based system can thus open up a new value added business to Sikkim cardamom as the transportation cost will be less if extracted oil is marketed instead

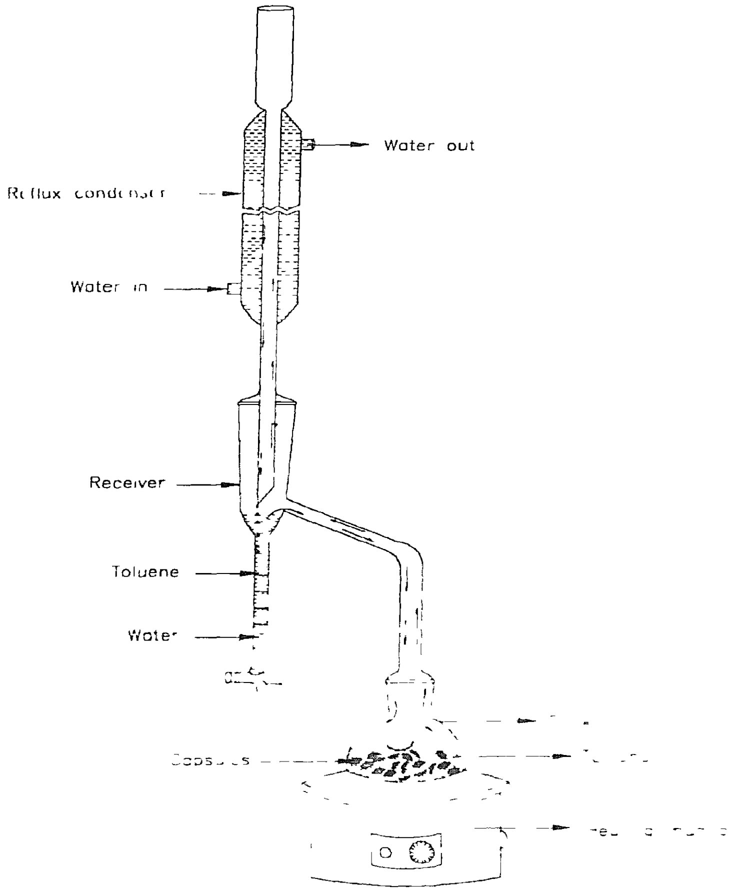


Figure 8.2. Schematic diagram of Dean and Stark apparatus for moisture content measurement

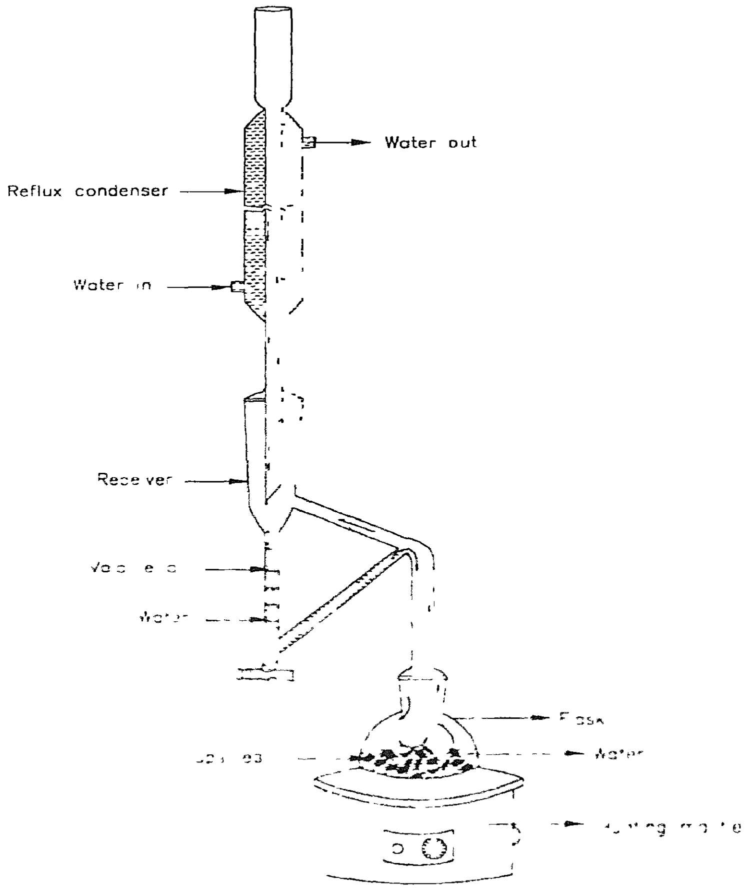


Figure 8.3. Schematic diagram of Dean and Stark apparatus for volatile oil content measurement

of whole cardamom. As mentioned earlier, large-cardamom oil can be a substitute for small cardamom oil. This, if proved and established in the market can change the nature of the whole large-cardamom business in Sikkim in the long run, increasing the income significantly. The present market price for large-cardamom capsules ranges from Rs 65-75 per kg as against Rs 300-400 per kg for small cardamom and oil extracted from small cardamom is presently sold at about Rs 8,000 per liter

Table 8.1. Summary of the comparative quality analysis data of large-cardamom

Location\ quality parameter	Volatile content (% v/w)				Moisture content (% v/w)			
	No of data points	Mean	Standard deviation	Variance	No of data points	Mean	Standard deviation	Variance
Cardamom cured in traditional *bhattis*								
In India	12	1.69	0.09	0.01	12	11.30	1.08	1.16
In Bhutan	6	2.05	0.13	0.02				
Cardamom cured in TERI's gasifier-based dryer system at different field testing sites								
Kabi	15	2.03	0.12	0.01	15	5.28	0.56	0.31
Assam Lingzey	18	2.37	0.27	0.07	8	10.79	1.83	3.36
Ravangala	12	2.20	0.13	0.02	6	9.47	2.64	6.97
Kaluk	6	2.34	0.25	0.06	5	9.79	0.52	0.27
Mangan	10	2.07	0.15	0.02	6	11.41	3.40	11.55

In the samples collected during trial field testing at Kabi very low (5.28%) moisture content was observed indicating complete and probably a little over-dried cardamom. However, in the samples collected during the extended field testing of system in the four districts of Sikkim during the harvesting season of 1997, wide variation in the moisture content levels was observed. Though in the majority of the samples moisture content was below or around the acceptable level of 10%, a few samples gave very high values indicating incomplete drying. In an inspection of all 28 bags of cardamom received in Delhi from Sikkim, it was observed that in some bags fungus formation occurred presumably due to higher moisture content in a few batches. The batches where high moisture content was possible are: (i) Third batch at Manul, Mangan where experimentation of washing cardamom before drying was tried. This might have misguided the farmer on turn out ratio (usually 4:1 or 5:1) of cardamom, (ii) First batch at Ravangala where very wet wood was used and (iii) First batch of Assam Lingzey which was the first experience with the new system Since during *kaichy* cut and packing (done in storage room at Rampool) cardamom from all the batches got mixed, it might have affected other dried capsules too during storage.

When a few samples gave high moisture content levels, TERI staff visited all the field testing sites and met the farmers to see whether fungus was there in other bags of cardamom which farmers dried on their own using the gasifier-based system Surprisingly there was no fungus attack even in a single bag and all farmers informed that in fact the cardamom dried in the gasifier-based system is intact even after several months of storage and they were very happy about it. Therefore, it is suspected that the fungus problem in the bags received in Delhi might be due to immediate storage of cardamom in plastic bags or due to the fact that the cardamom was not dried completely, as the price was assured by TERI

CHAPTER 9

Test marketing of improved quality large-cardamom

The major objective of trial test marketing study was to get a preliminary reaction of large-cardamom traders in the business to improved quality (Sikkim Grade I) cardamom obtained through the gasifier-based advanced drying system.

The other objective of the study was to judge the concept of quality of large-cardamom in domestic and export market and to see how much higher price can be obtained by the improved quality product

In order to get this information, TERI carried out a detailed and extensive questionnaire based survey-cum-test marketing exercise in some of the major trading centres of large-cardamom as well as with exporters of large-cardamom After the project review meeting in March 1998 it was decided to extend the project duration by 3 more months and get inputs from marketing consultants also to gather further information/feedback on market response to improved quality cardamom Accordingly a sub-contract was given to M/s Infocus Research and Field Services (P) Ltd, Delhi to give a report of large-cardamom market. Also an extensive survey of 1020 households/end-users of large-cardamom in nine colonies of Delhi was carried out with the help of M/s Shambhavi Agency, Delhi who are already trying to promote a product known as Spice Drop in the market This chapter gives detailed description of the efforts made by TERI as well as the marketing consultants to get the response of market and end-users to improved quality cardamom dried in gasifier-based system

9.1 Survey of large-cardamom trading centres

In order to get the desired information a detailed questionnaire was prepared (Annexure 4). Major trading centres covered included Delhi, Amritsar, Kanpur, Lucknow and Jaipur

During discussions with the traders/merchants detailed information about traditional *bhatti* system and the improved gasifier-based system was explained with the help of photographs A sample of the improved quality of cardamom was given to the trader to judge its superiority over traditionally cured cardamom available in the market Generally traders tested the quality by appearance, colour, feeling of moisture In order to judge the volatile content and the taste difference due to it, few capsules were broken and examined The survey results of various trading centres are given in the following sections The list of traders covered under the survey is given in Annexure 5

9.1.1 Delhi market

In old Delhi's wholesale market area of Khari Baoli there are 3 pockets dealing with large-cardamom Out of this survey was conducted in two pockets. Totally 7 merchants were interviewed in detail. Surprisingly it was observed that traders here are least bothered about volatile oil content and decided the price based on appearance, colour and size A few merchants initially got confused and said that it needs to be dried further. But when they broke open the capsule and on examination found that it is oil and not the moisture, they were convinced about the improved quality. The majority of the merchants in Delhi do business on commission basis Therefore they were unable to give an exact opinion on the possible extra price which improved quality cardamom can fetch in the market However, all the merchants unanimously agreed that the quality was better and said that such quality is rarely seen in the market All the traders said that if sufficient and, more importantly, regular supply is assured, they will be able to offer premium price to farmers They were of the opinion that the gasifier-based improved quality cardamom will fetch around 10% more price than traditional one and further increase will depend on consistency in quality and how the end-users reacts to it

9.1.2 Amritsar market

Unlike Delhi, Amritsar market is more export oriented and competitive as well as professionally managed As soon as the traders saw the improved quality product they got very impressed and a few offered an instant price of Rs 105–115 per kg as against the present market price of Rs 98 per kg for presently available best quality cardamom All the exporters were eager to book orders and gave their visiting cards (this type of response was different from Delhi market where people were hesitant to give comments and even names) Here, merchants appreciated quality not only for appearance and dryness but also for oil content One merchant even suspected that the capsules were artificially coloured after seeing purple tinge and was impressed when he finally realised that the colour was natural

On an average merchants feel that the improved cardamom can fetch at least 10–15% more price than the prevailing best price in the market However, even for trial test marketing traders needed a few tonnes of the produce and an assurance of regular supply with consistent quality in future

One of the suggestions which came from the traders was to launch the Sikkim Grade I cardamom in the form of 1, 2, 3 kg packets under a new attractive brand

9.1.3 Lucknow market

It is one of the major consumer markets for large-cardamom due to presence of a large muslim population. There are two major trading pockets (i) in Rakab Ganj where big traders doing retail business of large-cardamom are located, (ii) on Subhash Marg where major whole sale merchants are located. Though impressed by the good natural reddish colour of the cardamom obtained with the gasifier system, traders here felt that there is little chance that the improved quality will fetch very high (25%) premium, at least in the initial period. They felt that it may fetch a premium of about Rs 5-8 initially against the present market price of about Rs 85-95 per kg Everyone showed interest in marketing but not through outright purchase, but on commission basis The commission rates in cardamom and other spices business in Lucknow are 6 20%. Thus the supplier of cardamom has to deliver the goods to traders and on sale he will get back the money after deducting the commission In Uttar Pradesh form No 31 has to be filled before transporting the cardamom along with bill of materials The prevailing rate of interest for deposit and credit is 2% per month

9.1.4 Kanpur market

Like Lucknow, Kanpur is also a major consumer market but buyers are again not very quality conscious Here the traders generally sell cardamom in specially made 25 kg packets Also among the bold and small varieties they sort out the capsules as per colour and sale it at different rate They also sell cardamom imported from Bhutan Here also traders told that it is difficult to convince the customer/buyer on account of better oil content, but the improved appearance (colour) can fetch a price of about Rs 110-115 per kg against the prevailing price for best bold variety of about Rs 95-105 per kg Here the commission rates are a little lower at 5 0%

9.1.5 Jaipur market

Jaipur is a small city with regard to consumption of large-cardamom as compared to other cities but there is a demand as it is a tourist place and a number of hotels in and around the city exist There are two markets doing wholesale trading of large-cardamoms in Jaipur.

- Maniharon ki gali
- Dinanath gali

Being close to Delhi all traders procure large-cardamom from Delhi. All trading in Jaipur operates on commission basis Current commission rates are 6 2%. Colour of the cardamom was the center point of attraction The owner of Delhi Trading Company appreciated its high density and dryness also, when samples of improved quality cardamoms were given to him The prevailing rate of large-cardamom in Jaipur was in the range of Rs 85 to 90 per kg. According to their views, the product from TERI's gasifier can be sold at a premium of Rs 4 to 5 per kg over the present market rate

9.2 Study of large-cardamom market by Infocus Research and Field Services (P) Limited

In order to understand the acceptance of large-cardamom dried using the advanced gasifier-based drier, TERI appointed Infocus Research and Field Services Private Limited (Infocus) to conduct a study of large-cardamom market The study was conducted by Infocus during the month of June 1998 in Delhi and Amritsar. The objectives of the study were (i) to understand the existing market scenario for large-cardamom, (ii) to understand the dynamics of the existing distribution channels for large-cardamom, (iii) to gauge the reaction in the marketing chain to the sample large-cardamom dried using the gasifier-based drier, and (iv) to ascertain the acceptance level for the sample large-cardamom and the price premium that could be commanded While conducting the study, Infocus was also requested to explore the possibility of identifying potential buyers for the quality of large-cardamom being held by TERI, which had been produced from the trials using the gasifier-based dryer

The study was essentially carried out through in-depth interviews with a cross-section of segments involved in the large-cardamom trade such as (i) Agents/wholesalers of large-cardamom in Delhi, (ii) Masala manufacturing companies in Delhi, (iii) Mother Dairy, which has recently started selling large-cardamom through their existing retail outlets, and (iv) Exporters of large-cardamom in Amritsar

The reactions to the improved quality cardamom dried in gasifier-based system are

- In each segment that was covered under the study there was a general acceptance, that the sample cardamom was of good quality in terms of appearance, size, consistency in size and dryness.
- There was a clear acceptance that the sample was better than qualities available at present in the market and it would command a price premium of Rs 8 to 12 per kg
- Assurance of continuity of supply of the sample quality is a factor that the different segments would consider making their purchase decision
- Pricing is a factor that would determine volume offtake of the product It would be necessary to strike a balance on the pricing to derive, optimum benefit of the quality which is clearly perceived as being better

Infocus recommends that a co-operative society be set up at Siliguri or Gangtok to coordinate the following activities

- Promoting the use of advanced gasifier-based dryers at the large-cardamom grower level,
- Procuring the output from grower using these techniques for drying large-cardamom,
- Maximizing the procurement price paid to the growers;
- Co-ordinating the marketing efforts directed at the different segments of the large-cardamom business;
- Co-ordinating the market development activity and optimizing sales realizations from different segments,
- Monitoring technical developments that can upgrade yield and realizations at the grower level,
- Educating growers about newer techniques that can be adopted;
- Ensuring that surpluses generated are ploughed back into development at grower level etc

9.3 Survey of households in Delhi to access acceptability of improved quality cardamom

In order to assess the concept of quality with regard to large-cardamom in the minds of its ultimate user i e households, and also to get their response to improved quality cardamom, TERI felt a need to carry out survey of households in Delhi. This section summarizes details of such a study assigned by TERI to M/s Shambhavi Marketing Agency.

The objective of the assignment was

- to judge the concept of quality of large-cardamom as seen by the end-user i e. households of large-cardamom and
- to assess their response to improved quality large-cardamom capsules obtained through drying in the gasifier-based system being developed by TERI.

A comprehensive questionnaire (in local Hindi language) based door to door survey method was adopted in order to collect the required feedback/information from the user The questionnaire was designed in such a way that it collects information on two major issues of the study

- consumers view points regarding quality of large-cardamom i.e. why does the consumer buy/not buy a particular product like cardamom or in other words it tries to judge the concept of quality with regards to large-cardamom in the minds of user

- level of acceptability of improved quality cardamom i.e user feedback on quality comparison of improved quality cardamom with that dried traditionally

In all 1020 number of households (large-cardamom users) were surveyed in nine different colonies of western part of Delhi which is one of the major area of Delhi consuming large-cardamom.

9.3.1 User's concept about quality of large-cardamom

Through preliminary discussions with the retailers/wholesalers as well as few users following four quality parameters were identified in order to describe the quality of large-cardamom

(i) Colour/appearance
(ii) Taste (due to its volatile oil content)
(iii) Size of the capsule
(iv) Dryness of the capsule

It can be seen from Figure 9 1 that the most preferred qualities of large-cardamom in descending order are taste (37 06%), colour/appearance (29 02%), Size (24 31%) and dryness (9 61%) It was surprising that the dryness receives least preference among various quality parameters The reason for the same, as told to the surveyors, was that the users have no control on it or rather no option for the same

9.3.2 Feed back on quality comparison

After giving the sample packet of improved quality sample, users were asked to give their response on its quality by comparing it with the available cardamom with them from the market Figure 9 2 (a,b,c) gives the summary of survey response with regard to quality parameters such as colour/appearance and taste as well as to its offered premium price respectively

Colour/appearance

Majority of the users appreciated the better good looking cardamom dried in the gasifier-based system due to its distinct reddish/purple shade which is generally absent and also absence of fungus which is quite common in traditionally cured cardamom Some of the users even rubbed the capsules to verify that it is natural colour and not an artificial one From Figure 9 2(a) it can be seen that more than 70% users agreed that appearance of the new cardamom is better than that available presently in the market, while other 23% users felt it as similar and only negligible (less than 6%) users responded adversely

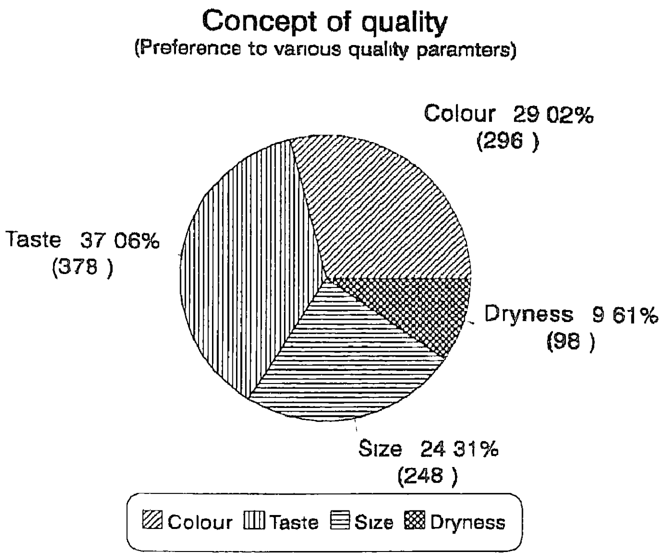
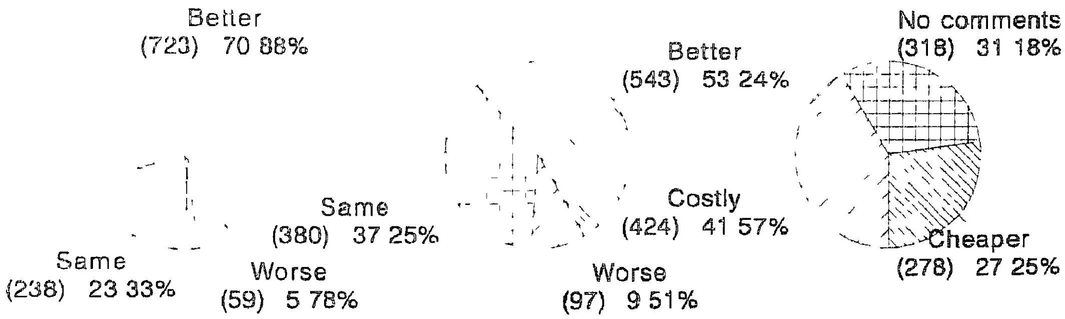


Figure 9.1. User's preference to various quality parameters



(a) Apperance/colour (b) Taste (c) Offered price

Figure 9.2. Survey response for quality comparison

Taste

Here the response was not that instant and favourable like colour/appearance, probably it was not that easy to judge or appreciate the taste. Users were asked to break open the capsules from the given sample and chew the inner seeds in order to feel and judge the taste difference

From Figure 9.2(b) it can be observed that more than 53% users felt that it tastes better while 37% users felt it same as normal cardamom and only 10% felt it is worse Some users told that this cardamom can be chewed as it gives better taste and pleasant smell and expressed their surprise to the fact that it does not give burnt-chary smell and taste. A few users even suggested that due to this quality it can be even used as a flavouring agent like the small cardamom and may have good market for such an application.

Assessment of premium price

Surveyors were given three different premium price levels of Rs 160, 180 and 200 against prevailing market price of Rs 140-150 per kg The survey response giving opinion of the user, whether it would be cheaper/costlier, taking into account the quality comparison is shown in Figure 9 2(c)

More than 27% users felt that even at premium price it would be cheaper due to its superior quality in terms of good appearance, better taste and absence of fungus About 31% user agreed superiority of the produce but rather took a wait and watch approach by either not giving any comment or by saying that if consistent good quality is maintained it would definitely fetch better price in due course

CHAPTER 10

Project review workshop

The main purpose of organizing the workshop was to review the progress made in the development of the advanced gasifier-based cardamom dryer in Sikkim under the Action Research Phase of the project and to plan the activities for the future. Another objective was to elicit comments/feedback from the concerned professionals from state and central government departments, farmers, marketing experts etc on system design and performance in the field This was necessary so as to assess the success of the action research phase of the project and to take a decision whether to go ahead with the second phase of the project i e pilot scale plants during the next year's cardamom harvesting season This one day project review workshop was organised at Hotel Chumbi Residency, Gangtok on 29 June 1998.

The participants of the workshop included officials from ISPS (Indo-Swiss Project Sikkim), SDC (Swiss Agency for Development and Co-operation), Department of Agriculture, Horticulture and Industries, Government of Sikkim, Spices Board, AILCGA (All India Large-Cardamom Grower's Association), Cardamom Farmers selected for field testing, Cardamom traders, TERI (Tata Energy Research Institute), G.B Pant Institute, and Marketing Consultants Representatives of financial institutes like NABARD (National Bank for Agriculture and Rural Development) and SBI (State Bank of India) also attended the workshop. The list of participants is given in Annexure 6

The workshop started with a welcome address by Dr P J Joseph (LO/ISPS) who gave information about ISPS activities in Sikkim and how this project was evolved After giving a brief account of activities under cardamom drying project for the last couple of years he informed the participants about the purpose of this workshop and what is expected to be achieved during the day-long deliberations.

Dr Kishore (Senior Fellow, TERI) gave a brief account of TERI's activities describing the involvement of TERI and its efforts to develop energy efficient dryers for cash crops including cardamom since 1983 In 1983, TERI sponsored a study on drying of small cardamom to a college in South India, which may be the first study of its kind, and that followed by a DST sponsored project, executed by TERI, on development of an efficient dryer for small cardamom in south India Major achievements of this project were 50% fuel saving and lesser drying time

Later on he gave salient features of TERI's present project in developing an appropriate system for improving the quality of large-cardamom in Sikkim and for improving the energy efficiency of drying by development of a gasifier-based system The major achievements are 60% fuel saving and quality improvement of dry cardamom in terms of better appearance, 35%

more oil and 25% time saving He stressed the possibility of opening up of new business opportunities for large-cardamom in Sikkim such as oil extraction industry, as now with gasifier-based dryer more oil can be obtained without burnt smell to it At the end he expressed the need to critically evaluate the efforts and achievements of TERI during the action research phase of the project as it will help to improve it further and hoped the collaborative effort will result in improving the large-cardamom activity in Sikkim.

In his presidential address, Mr P Bhutia (Secretary/Horticulture) gave a brief history of cardamom in Sikkim He also explained how traditional *bhatti* system of curing cardamom in Sikkim is an energy inefficient (consumes lot of fuel wood, thereby endangering ecological balance of Sikkim by rapid deforestation) and slow process resulting in poor quality cardamom He appreciated TERI's effort in developing an advanced gasifier-based dryer system which is simple and appropriate for conditions in Sikkim and hoped that it will prove to be economically and socially acceptable to cardamom growers

Mr S W Tenzing (Additional Chief Secretary) formally inaugurated the workshop by welcoming the participants, specially the cardamom grower community and farmers from previous field testing sites.

Presentation I: Devlopment of gasifier-based dryer system for curing of large-cardamom in Sikkim by Mr Sanjay Mande (Fellow/TERI)

In his presentation Mr Mande gave detailed step-by-step account of R&D efforts made by TERI in developing the advanced gasifier-based system during the two year long action research phase and the field performance details of the system developed Initially the analysis of traditional *bhatti* was presented so as to understand why it gives poor thermal performance as well as poor quality produce Then the efforts made by TERI in developing simple, low cost gasifier design were described Emphasis in developing the alternative design was to evolve a system which will be suitable for field conditions in Sikkim The main features of the gasifier design developed are

- low cost and simple design to fabricate in workshops of rural areas
- light weight individual components, making it transportable in hilly areas
- no need of electricity to operate the system
- system can be used as an attachment to the existing traditional *bhatti*

The major achievements proved through successful field testing of the system at Kabi in 1996 and at four field testing sites in 1997 are

- improved thermal performance of the drying process, more than 60% fuel saving
- improved quality of dry cardamom. better colour/appearance (retains natural reddish colour)
- retains more (>35%) volatile oil content in the dried cardamom without burnt smell
- trial test marketing gave encouraging response showing acceptability of the improved quality cardamom by end-users indicating possibility of 10-15% premium on price

Presentation II: Improved quality large-cardamom dried using gasifier-based system – market response by Ms Rashmi (Market Consultant)

M/s Infocus Research and Field Services Private Limited were awarded an assignment to assess the market response of large-cardamom cured under gasifier system. Mr Sridhar carried out field studies in the trading centres of Delhi and Amritsar Ms Rashmi presented the findings of the study She gave detailed account of field survey work carried out in Delhi and Amritsar market and some of the masala manufacturing companies in Delhi The overall response towards improved quality was encouraging She told that "Mangan" grade *kaitchy* cut cardamom is favoured much but is in less demand due to its maximum price. The sample given was perceived by traders as Mangan variety and it was told that it can be in demand in cities like Karachi where good quality cardamom is preferred

In conclusion she suggested formation of a cooperative which can market the improved quality cardamom in retail market directly at a premium price under a brand name. Initially premium of the order of Rs 10-15 per kg can be expected

Presentation III: Functional framework for the cardamom curing cluster in Sikkim by Ms Ariane Waldvogel, SDC

In order to initiate discussion on how to promote the gasifier-based system in the cardamom curing clusters of Sikkim, Ms Ariane gave brief outline for marketing Here she proposed a possible organizational framework involving the manufacturer, commercial-cum-marketing agents, TERI/ISPS/Consultants, financiers, farmers and Sikkim Government along with their possible inter-linkages and roles Some of the issues raised during the presentation include

- mode of identification of manufactures and commercial agents/entrepreneurs
- identification of the existing formal/informal financial support mechanisms for the farmers and/or marketing agents in Sikkim, and the possibility of using these for market development She also said that it would be useful to undertake a comprehensive socio-economic study of the cardamom curing clusters of Sikkim

Important points made by farmers:

Mr P G Tenzing, Mangan, North Sikkim

- Some farmers have several small pieces of land and it may not be possible for him always to arrange dry wood at all sites It may be easier to manage it at sites where the farmer has a home.
- Durability of the system components should be given due consideration while manufacturing
- It was observed that on some occasions the starting time was too long to stabilize gasifier operation which needs to be shortened
- Is it possible to vary the gasifier size? Smaller size for small holding and larger size for large holdings should be considered.
- Can gasifier be horizontal so as to reduce the overall system height?
- Presently ceramic and mineral wool blanket is used as duct insulating material Any local alternative for it would be desirable

Mr Ambiraman Rai, Assam Lingzey, East Sikkim

- System is good, convenient, takes less time
- Chances of fire hazards are less with gasifier system due to absence of flying burning particulates
- Colour of dried capsules is definitely much better in appearance
- All the tails can not be removed, has to employ labour for *kautchy* cut
- Manpower is required to cut available fire wood into pieces
- Substantial difference in fuel consumption is not obvious
- Regular fire wood charging (every 2 hours) needs continuous attention of operator
- More than 10-15 Rs premium needed to justify the use of gasifier system

Mr Ongay Topden, Ravangla, South Sikkim

- Needs more labour to cut dry wood into pieces
- Complete tail removal can not be achieved Tail has to be removed manually
- Obtaining dry fuel wood may be a problem

Mr I B Gurung, Kaluk, West Sikkim

- Quality of dried cardamom by gasifier is very good in comparison to the cardamom dried by traditional system.

- The cardamom dried in November last year is still as it is without any traces of fungus (which is quite common with traditional *bhatti*)
- It reduces fuel consumption by 75%.
- If fire wood is dried and cut in advance the system is very useful and convenient.
- There is substantial time saving.

Mr Mande gave point-wise reply/comments to queries raised by farmers on field testing of gasifier-based dryer and their expectations about it.

- Dry wood is essential for smooth and reliable gasification process Wet wood with higher moisture content can not be used as then it becomes difficult to retain high temperatures inside gasifier which is essential for the gasification process i.e. the process of obtaining combustible gas from solid wood fuel
- It is easy to increase the size of gasifier if required with some additional cost.
- Since the cheap option of empty oil drum is used to make the present gasifier, it would be better to use same instead of going for smaller size and to charge fuel less frequently.
- Horizontal gasifier design is not possible
- Durability of the system components can definitely be improved through quality control in manufacturing
- More start up time problem might have been experienced whenever wet wood is used as otherwise with dry wood it should be less than an hour
- Incomplete removal of tails is a general problem and not a specific problem with a gasifier-based system It depends entirely on the extent of drying, removal of moisture below certain level and rubbing capsules when hot, which was not done during field testing by farmers
- Occurrence of fungus is also not a technological problem but more of an operational practice problem If moisture content is brought down below certain level (< 10%) by any system/technique it should not lead to fungus problem.

Some of the major suggestions/points made by various participants during the discussion are summarized below

- Improving the system for increasing the durability, reliability of operation and user friendliness
- Improving the *bhatti* design too in order to improve the overall system performance
- Reducing cost further, if possible
- Modifying *bhatti* design to try cardamom bed in several thin/mono layers

- Modifying *bhatti* design to create space for packing wood for drying
- Try to use local material as far as possible e.g. for duct insulation etc
- Possibility of extending the application of the system to other areas of interest e.g ginger drying, food grain drying etc.
- Developing a wood chopping machine

Dr Joseph said that the presentation by TERI and market consultant gave findings of the action research phase which gave an encouraging picture, and the farmers expressed satisfaction over the systems capacity to improve the quality of dry cardamom Marketing study showed that traders as well as users appreciated the improved quality of cardamom and there should not be much difficulty in attracting better premium The participatory and fruitful discussion for critical review of action research phase indicates need for a pilot scale phase so as to obtain sufficient quantity of improved quality cardamom to judge its possible impact The workshop ended with vote of thanks by Dr Joseph.

CHAPTER 11

Conclusions

In the Action Research Phase of this project, sponsored by ISPS, TERI had developed an advanced gasifier-based large-cardamom drying system and successfully field tested it at various sites in all the four districts of Sikkim During the first year of the two year action research phase of the project, the conceptualization of system design was done and a laboratory prototype was developed and tested at TERI's Gual Pahari campus After successful development of the system it was field tested at Kabi (North Sikkim) during 1996 cardamom harvesting season in order to get first hand experience and feedback about system performance under actual field conditions Successful trial field testing of the system at Kabi gave sufficient confidence in the system design i e using an updraft gasifier for improving thermal performance of large-cardamom dryer as well as improving the quality of large-cardamom.

During the first year of the action research project, efforts were also made to get basic drying characteristics of large-cardamom through in-depth laboratory experiments at IIT Bombay with the help of Prof V G Rao This helped in generating basic information about drying parameters such as critical moisture content, drying rates and drying time under various operating conditions It proved that ideally it is possible to dry the large-cardamom in less than 15 hours

Based on the feedback received and experience gained during trial field testing the system design, layout as well as configuration was changed to make it more easy to fabricate, install and operate The gasifier is now placed outside the *bhatti* so that smoke can be kept away from the cardamom bed during gasifier start-up (ignition) period as well as during subsequent fuel charging interval Gasifier insulation was changed from in-situ casting to pre-cast rings which made individual system components light This will help in fabricating the system at a centralized place and transporting it easily to remotely located cardamom plantations for installation A modified fuel charging top cover with a lever mechanism helps in feeding larger size wood pieces quickly.

During the 1997 cardamom harvesting season the improved system was successfully field tested at four selected sites one each in all four districts of Sikkim In all 27 batches of cardamom were dried using the gasifier system producing over 3 metric tonnes of improved quality cardamom Out of these four field testing sites two were difficult sites to approach (away from the road), which proved the transportability of the system in remote hilly areas of Sikkim Operation of the system even in the absence of TERI staff proved that the system was acceptable to the farmer and that he can operate it independently without elaborate training.

The response received during test marketing of improved quality cardamom in major trading centers of Delhi, Amritsar, Lucknow, Kanpur and Jaipur was quite encouraging. Everyone appreciated the better appearance and colour of cardamom dried using the gasifier-based system. It gave indication that if supplied regularly and with consistently better quality the cardamom dried in the gasifier-based system can fetch good premium, increasing income to the farmers The survey of about 1020 households (end-users of cardamom) in Delhi also proved the acceptability of improved quality cardamom.

During the project review workshop held in June 1998 the progress made during action research phase of the project in developing gasifier-based dryer system was reviewed and it was decided to go ahead with the pilot scale phase of the project With the background of the successful field testing of the system the objective of the pilot scale phase should be to make several systems and get these fabricated by the fabricator independently in Sikkim, allow farmers to use these on their own with prior training This will help in assessing the acceptability of the system by more farmers Some improvisation of the system can be done so as to make it more user friendly, based on inputs received in the project review workshop

Once a substantial quantity of the improved quality cardamom comes into the local market it will also help in getting a realistic reaction of the local traders, which in turn will decide future strategies for widespread dissemination through commercial mechanisms

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Annexure 1

List of farmers surveyed to ascertain acceptability of gasifier-based cardamom dryer

Sr. No.	Name of the owner	Location
1	Kaching Bhutia	Kabi, North Sikkim
2.	Sonam T. Bhutia	Kabi, North Sikkim
3	Ugen Tshewang	Kabi, North Sikkim
4.	Karsang Lugaden	Kabi, North Sikkim
5	Lopsung Bhutia	Kabi, North Sikkim
6	Anki Bhutia	Kabi, North Sikkim
7	N T Bhutia	Kabi, North Sikkim
8.	Gheising Lama	Phodong, North Sikkim
9	Tshering Bhutia	Thingching, North Sikkim
10.	Lhakchun Bhutia	Thingching, North Sikkim
11	Tashi Lepcha	Mangan, North Sikkim
12	Tempa Bhutia	Mangan, North Sikkim
13	Thinlay Namgyal	Singhik, North Sikkim
14	Tshering Wangdi	Singhik, North Sikkim
15	Norjee Lepcha	Singhik, North Sikkim
16	Tshewang Dorji	Manul, North Sikkim
17	Ang Lepcha	Ambithang, North Sikkim
18	Sonam Topgay	Malling, North Sikkim
19	D Tshering	Mangan, North Sikkim
20	S Dadul	Mangan, North Sikkim
21	Zigme Ongda	Mangan, North Sikkim
22	Saty Bhutia	Pakyong, East Sikkim
23.	Sonam Korji Kazi	Pakyong, East Sikkim
24	K B Gurung	Pakyong, East Sikkim
25	Padma Lackson	Pakyong, East Sikkim
26	Sonam Tshering	Pelling, West Sikkim
27	Mingyur Tenzing	Pelling, West Sikkim
28	D S Gurung	Pelling, West Sikkim

Sr. No.	Name of the owner	Location
29.	Dharma Singh	Pelling, West Sikkim
30	Shanti Martah	Soreng, West Sikkim
31	Devi Lal Pande	Soreng, West Sikkim
32.	Til Bahadur	Soreng, West Sikkim
33.	Mohan Kumar	Soreng, West Sikkim
34	Bhagar Singh	Soreng, West Sikkim
35.	Tara Subba	Soreng, West Sikkim
36.	Ran Bahadur	Soreng, West Sikkim
37	Narayan Dhoj She	Soreng, West Sikkim
38	D T Bhutia	Ravangla, South Sikkim
39	Purna Bahadur	Ravangla, South Sikkim
40	Karma Tshering	Ravangla, South Sikkim
41	Lozang Bhutia	Ravangla, South Sikkim
42	Pinchoo Bhutia	Ravangla, South Sikkim
43	Sukman Gurung	Ravangla, South Sikkim
44	Tikaram Gurung	Ravangla, South Sikkim
45	Rinzing Sherpa	Ravangla, South Sikkim
46	Jigmee Tachi	Ravangla, South Sikkim
47	Krishna Bahadur	Ravangla, South Sikkim

Annexure 2

Questionnaire used to assess acceptability of gasifier-based cardamom dryer

A. General information

Owner's name

Address (village)

Journey time from Gangtok and distance

Cardamom dried in each *bhatti* (kg) per person Total

B. *Bhatti* details

Cost of the existing *bhatti* (Rs)

How often is it replaced by a new one

How many times is it repaired, and cost incurred in repair per season

Wood used per drying session (kg) per *bhatti*

C. Benefits and constraints of improved *bhatti* with gasifier

Constraints of improved bhatti (the most difficult one ranked first and so on)

Initial cost (Rs 2000/-) of the gasifier

Needs dry wood (but 50% less)

Needs cut wood (4 × 6" pieces)

Gasifier too heavy (200 kg) for mobility

Likely benefits of improved bhatti (the most beneficial to be ranked first)

50% fuel saving	Better quality of product
Less time for drying	Lower labour due to lower fuel consumption

D. Whether farmer willing to try improved *bhatti* Yes/No

E. Additional remarks

Annexure 3

Experimental data for quality analysis of large-cardamom

Traditional Bhatti in India

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	1.70	10.26	7	1.70	10.68
2	1.64	13.38	8	1.55	10.15
3	1.60	10.64	9	1.80	12.59
4	1.73	12.47	10	1.70	10.34
5	1.55	11.88	11	1.72	10.28
6	1.80	12.14	12	1.80	10.77

Traditional Bhatti in Bhutan

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	1.86		4	2.00	
2	2.10		5	2.20	
3	2.20		6	1.96	

Kabi (North Sikkim)

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	2.00	5.28	9	2.18	5.52
2	2.20	4.37	10	2.08	5.74
3	2.01	6.78	11	2.15	4.97
4	1.73	4.67	12	1.94	4.76
5	2.00	5.48	13	1.94	5.15
6	2.00	4.72	14	1.95	5.24
7	2.10	5.28	15	1.99	5.57
8	2.16	5.68	16		

Assam Lingzey (East Sikkim)

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	1.75	10.18	10	2.20	
2	2.40	8.55	11	2.30	
3	2.90	14.71	12	2.33	
4	2.60	9.76	13	2.50	
5	2.61	10.48	14	2.00	
6	2.60	11.43	15	2.29	
7	2.70	12.11	16	2.10	
8	2.60	9.12	17	2.25	
9	2.20		18	2.33	

Kaluk (West Sikkim)

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	2.50	9.64	4	2.00	9.87
2	2.50	8.90	5	2.00	10.16
3	2.40	10.4	6	2.65	

Ravangala (South Sikkim)

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	2.40	10.11	7	2.10	
2	2.40	6.94	8	2.29	
3	2.20	14.86	9	2.10	
4	2.40	8.57	10	2.10	
5	2.20	9.12	11	2.10	
6	2.10	7.23	12	2.00	

Mangan (North Sikkim)

Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)	Sample No	Volatile oil content (%w/v)	Moisture content (%w/v)
1	2.29	8.72	6	2.00	13.84
2	2.10	9.33	7	2.10	
3	2.00	17.55	8	2.10	
4	2.10	7.65	9	1.90	
5	1.80	11.36	10	2.30	

Annexure 4

Questionnaire used to carry out trial test marketing study

Date .
Place

1. Name

2. Address:

3. What is definition of quality of large-cardamom (*badi or moti elaichi*) in market What is generally demanded in market as good quality product. (can give weightage to each factor in % and order of priority)

Overall appearance
Colour
Size
Oil content
Moisture content

4 Comparison of TERI-Sikkim Grade I large-cardamom dried in advanced gasifier-based dryer with traditional large-cardamom capsules

	Better than conventional	Same as conventional	Worst than conventional
Overall appearance			
Colour			
Size			
Oil content			
Moisture content			

5 How much extra will you be willing to pay for better quality (appearance oil content etc.) of capsule over and above traditional quality of large (*badi or moti*) cardamom (*elaichi*).

Due to colour or appearance

Due to more oil content

6. Area of marketing or export.

Where are you selling/marketing large-cardamom at present:

(a) in India

(b) outside India

7 Price levels for large-cardamom seen in past two years

Variety	
Average price (Rs/kg)	
Minimum price (Rs/kg)	
Maximum price (Rs/kg)	

8 How much extra will you think better quality (appearance oil content etc) of capsule will fetch in market over and above traditional quality of large (*badi or moti*) cardamom (*elaichi*)

Due to colour or appearance

Due to more oil content

9 If some farmers from Sikkim where we will be testing advanced gasifier-based system in next harvesting season will supply you this better quality Sikkim Grade I large-cardamom,

(a) how much quantity would you be requiring to test market it.

(b) what price will be willing to offer.

10 Do you have some innovative suggestion to test market the new Sikkim Grade I large-cardamom capsules in the market and to assess merchants/people's reaction to it for its acceptability and to judge how much extra it can fetch in domestic as well as export market

Annexure 5

Trial test marketing study of improved quality large-cardamom

List of traders surveyed during trial test marketing of large-cardamom

Sr. No.	Name of the owner	Location
1.	A S Gulati	6512-13 Chowk Feteh Puri Khari Baoli Delhi 110 006
2	Sagarmal & Ashok Kumar	42, Gadodia Market Khari Baoli Delhi 110 006
3.	Satnarayan Pawan Kumar (Commission Agent)	37-A, Gadodia Market Khari Baoli Delhi 110 006
4.	Mahesh & Company	21, Gadodia Market Khari Baoli Delhi 110 006
5	Manoj Kumar Pawan Kumar (Commission Agent)	2, New Gadodia Market Khari Baoli Delhi 110 006
6	Rakesh Jain	New Gadodia Market Khari Baoli Delhi 110 006
7	Tirkha Ram Ohm Prakash	Katra Iswar Bhawan New Gadodia Market Khari Bawli Delhi 110 006
8.	Anoop Kumar Maheshwari Dil Bahar Mundhra Trading Co	6699, Khari Baoli Delhi 110 006
9	Rakesh Sharma Shambhavi Agency	3/4951, Shiv Nagar Karol Bagh New Delhi 110 005
10	Rajeev Goswamy, Director Prime Horti-agro Projects Limited	B-18, Som Dutt Chamber-I 5, Bhikaji Cama Place New Delhi 110 066
11	Ramashankar	New Gadodia Market Khari Baoli Delhi 110 006

Sr. No.	Name of the owner	Location
12.	Ritesh Kapoor (Importer Exporter) Nimish International Spices	Bagh Jhanda Singh Amritsar 143 001
13.	Davinder Singh (Importer Exporter) Vikrant Overseas	Majith Mandi Amritsar 143 001
14	Jagadish Kumar Hari Om (Importer Exporter)	Majith Mandi Amritsar 143 001
15	Laxmi Narayan Ramesh Kumar (Importer Exporter)	Majith Mandi Amritsar 143 001
16	Banian Di Hatti	Sultan Pind Road Amritsar
17	Surinder K Sindhwani Shivanditta Mal & Co.	Majith Mandi Amritsar 143 001
18.	Jia Lal Kapoor Nimish International Spices	Bagh Jhanda Singh Amritsar 143 001
19	Subash Agarwal Aggarwal Trading Co.	Majith Mandi Amritsar 143 001
20	Pritam Singh Tara Singh & Sons	Swank Mandi Amritsar 143 006
21	Delhi Trading Co	556, Maniharon ka rasta Jaipur-3
22	Shantilal Jaigopal	361-B, Jaipur-302 002
23	Narayandas Chatendas	92-93, Jaipur-302002
24	Damodardas Ramsharandas	359, Tripolia Bazar Jaipur-302002
25	Chanandas Parmanand	354, Jaipur-302002
26	Tambi Trading Co	347,Tripolia Bazar Dinanath Gali Jaipur-302002
27	Gaindilal Roopnarayan Maheshwari	366, Tripolia Bazar Jaipur 302 002
28	Krishna Gopal Ashok Kumar Agrawal Sawaria Sales Corporation	215/53, Subhash Marg Lucknow - 226 003
29	Sri Niwas Agrawal Vishal Trading Company	Subhash Marg Lucknow 226 003

Sr. No.	Name of the owner	Location
30.	Ramesh Kumar Agrawal Shanti Traders	51/7, Ram Ganj Naya Ganj Kanpur - 208 001
31.	Sitaram Sanjay Kumar Sunil Kumar Prasad	53/27, Naya Ganj Kanpur 208 001
32.	Thigyal Lakar, Managing Director Labott Private Limited	Lakar Building Arithang Road Gangtok, Sikkim 737 121
33	Ramdeo Uday Shankar	Lal Market Singtam, (SIKKIM)
34.	Ajay Uday Shankar Sandeep Trading Company	Nehru Road, Siliguri
35	Jeremie et sabah bianchi	25, rue d'orset 75018 Paris France

Annexure 6

List of participants: project review workshop held on 30 June 1998 at Gangtok

Spices Board (4)
1. Dy Director (Dev)
2. Dy Director (Res) Representative
3. Asstt Director (Mkt)
4. Market Intelligence Officer

Horticulture/ Agriculture (9)
1. Secretary, Agri/Horti
2. Principal Director/Horti
3. Principal Director/ Agri
4. Director/ Horti
5. Addl Director/Horti (I)
6. Sr Project Officer (Spices/ Plan)
7. Sr Project officer (Spices/CSS)
8. Project Coordinator/Horti
9. Dy Director/Mktg

GB Pant Institute (2)
1. Research Scholar
2. Research Scholar

NABARD (1)

Officer in Charge

Lead Bank, SBI (1)
1. Manager (Representative)

Industries Department (1)
1. Director (Represented as partner farmer)

Partner farmers (3)
1. IB Gurung
2. Abirman Rai
3. Ongay Tobden

AILGCA (2)
1. Pemzang Tenzing, President
2. Pema Namgyal, Member

Traders (2)
1. Trader from Gangtok
2. Trader from Gangtok

ICAR (2)
1. Joint Director
2. Scientist

ISPS (4)
1. Liaison Officer
2. Project Executive
3. Representative of SDC/ Delhi
4. Representative of SDC/ Delhi

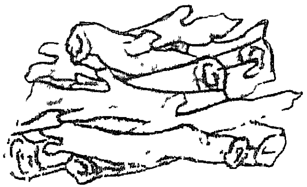
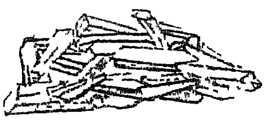
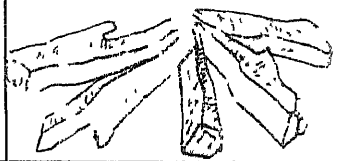
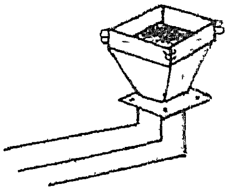
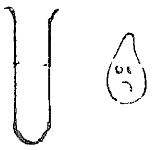
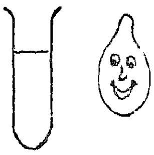
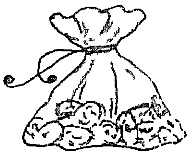
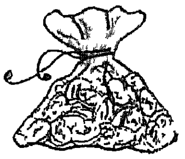
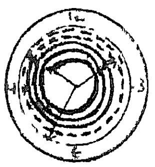
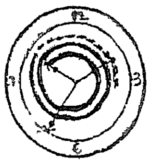
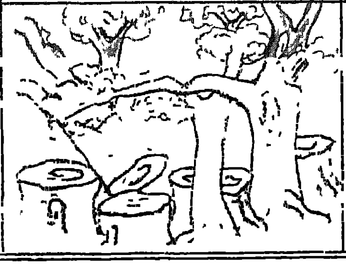
TERI, New Delhi (4)

1. Sr Fellow, TERI Delhi
2. Fellow, TERI, Delhi
3. Research Associate, TERI-North East
4. Technical Assistant

Infocus Research and Field Services (P) Ltd. Delhi

1. Mr S Sridhar
2. Ms Rashmi

dvantages of gasifier based dryer over traditional *bhatti* system

Traditional *bhatti* system		**Gasifier based large-cardamom dryer**	
onsumes huge quantities of uelwood logs pecific fuel consumption -4 kg per kg fresh cardamom apsule stimated fuelwood wastage 0,000 MT/yr		- More than 60% fuel saving - Specific fuel consumption 0.5-0.8 kg per kg fresh cardamom capsule - Pruning can be used instead of wood logs	
Vet wood logs gives smoky urning operation luctuating uncontrolled urning, prone to fire hazards oor operating thermal fficiencies 5-15%		- Wood gas from gasifier gives clean burning without smoke - Steady controlled burning of gaseous fuel - Higher thermal efficiency of the order of 30-35%	
xposure to smoke makes ardamom blackish-smoky Uncontrolled fire results in ocalized heating/ charring of apsules		- Clean burning helps in retaining natural reddish colour of capsule - Controlled burning results in uniform drying	
Cardamom oil, if extracted, gives char smell Very low (1.7%) volatile oil ontent due to uncontrolled/over heating		- Extracted cardamom oil retains pleasant smell - Retains 35% more volatile oil in cardamom (2.3%) due to controlled heating	
Oil extraction is not done at present due to its burnt/ charred smell Poor quality of traditional cardamom unable to enhance export or fetch higher price		- Potential to open up new oil extraction industry - May help in increasing export of large cardamom - Expected to fetch premium price, increasing income	
Takes much longer drying time (36-48 hrs) So tendency to dry 3-4 days harvested quantities in one batch resulting in poor quality		- Takes comparatively less time for drying (24-30 hrs) - Every day new fresh lot/ batch can be dried giving improved quality	
Huge consumption of fuelwood eading to rapid deforestation ates and ecological imbalance oss of natural beauty may danger tourism major income ource		- Eco-friendly technology - Can help in maintaining ecological balance by retarding deforestation - Can help in retaining tourism activity by preserving natural beauty